UNIVERSITY of SOUTH FLORIDA
Patel College of Global Sustainability

Research Paper

Sustainable Practices for Long-Term Olive Grove Growth from Palestine, Jordan, and Israel to Florida: Lessons Learned.

Renad Uri U07028757

July, 23rd 2021

Lessons Learned: Sustainable Practices for Long-Term Olive Grove Growth from Palestine, Jordan, and Israel to Florida.

Master of Arts in Global Sustainability
Sustainability Research Final Report

By:

Renad Uri

Supervisor:

Dr. Kebreab Ghebremichael

University of South Florida
Patel College of Global Sustainability

July, 23rd 2021

Abstract

Research on the history and cultivation requirements of olive trees in both Florida and the Middle East has not shown any prior research on irrigation best practices that put both regions alongside each other in a method of comparison. Therefore, this study will compile best practice techniques and recommendations for changes moving forward in the olive cultivation industry. This study aims to assess the current system in Florida in terms of irrigation of olive groves; additionally, the study investigates possible best practices from the Middle East to be used in Florida and vice versa. Finally, this research compares water stress mitigation strategies from the Middle East to Florida. That being said, a conclusion will be developed that includes recommendations for both regions, which will allow for the creation of a more sustainable olive grove cultivation.

Both regions can adopt best practices concerning sustainable olive grove cultivation through proper irrigation and management methods to test the hypothesis. This research hypothesizes that if best practices from Florida and the Middle East are commingled, advanced olive grove cultivation will occur. By interviewing seven professionals from the field in all of Florida, and the Middle East, both farmers and agricultural specialists were asked the same questions. Their responses were analyzed using a mixed-method approach and by utilizing thematic analysis.

This analysis showed that water sustainability is only one of many issues that have been a challenge to olive grove farmers. Farmers in the Middle East have experienced most challenges mentioned by Floridian farmers and have shared mitigation best practices. A significant take-a-way for Palestinian farmers could be the positive shift of perspective on wastewater treatment and its use as a source for irrigating olive trees since Florida is known to have reclamation facilities around the state. Additionally, Florida is as advanced as California in reclaimed wastewater use for irrigation and other non-potable uses; the regions could then collaborate and expand their efforts.

Acknowledgments

I want to express my most profound appreciation to Professor Ghebremichael and Professor Hanson for their continuous support during the entire process, from choosing the topic to the process of stress and time management before submission. Additionally, I am thankful for my family, who supported me during this entire time. Finally, I would like to extend my deepest gratitude to all those I had the honor of interviewing for the ultimate success of my research, Nada Majdalani, Kassim Abdo, Rami Massad, Asad AlKhader, Dede Rizzo, Lynn Dettenmayer, and finally Michael Garcia.

I owe it all to my country Palestine and its people to whom I am forever indebted to.

Table of Contents

List of Tables

List of Notations

DI	Deficit Irrigation
UF IFAS	University of Florida Institute of Food and Agricultural Sciences
MENA	Middle East and North Africa
USAID	United States Agency for International Development

1. Introduction

1.1 Background

The history of olive trees in the Middle East is ancient and has been a central element of Mediterranean agriculture for centuries (Loumou, 2003). Archaeological and scientific evidence shows that farmers found the original olive along the Eastern Mediterranean, specifically "the Levant" or Syria, finding its way to Palestine, Israel, Jordan, Lebanon, Greece, Italy, France, and Spain (Ghose, 2013). Olives and olive oil are long-lasting foods when harvested, a commodity that is unlike fresh produce that rots due to excessive sun exposure. The oldest olive tree is about 1500 years old, with the average lifespan of the tree being 500 years (Theorner, 2020). They prosper in sandy, well-drained soil; it is a requirement that they get full sun and a long heated growing season; when the trees are being cared for in such conditions, they will begin to bear fruit, and as the tree ages, additional production is expected (The Science Times, 2019). Figure 1 below shows the location of Jordan, Palestine, and Israel on the map; the areas included in this research are neighboring Egypt (North Africa), Syria (Levant), and Saudi Arabia (Gulf) (Khalidi, 2013).

Figure 1

Jordan, Palestine, and Israel are on the map.

Note. “Jordan and its neighbors” By Wikimedia Commons/Public domain, retrieved from Khalidi, 2013.

Additionally, Figure 2 below shows the different regions in Florida, some of which will be put forward throughout this research (Wild Florida, 2020). It is critical to note geolocations when discussing olive tree placement due to its effect on the ultimate success of the grove.

Figure 2

Florida Regions Map.

Note. Florida Regions Map, By Wild Florida.

The required environment for a thriving olive tree is similar to that of the State of Florida, and with that said, Florida growers have noticed this "cash crop.” Richard Williams, the owner of Florida Olive Systems, described it when he said, "there is the fruit, there is the oil, and then there are the leaves that are popular in teas and are

getting attention from the natural supplements market for their medicinal qualities' (Mchpherson, 2015). With 75 percent of Florida's oranges lost to huanglongbing or HLB, also known as citrus greening, Floridian farmers have taken to liquid gold, also known as olive production (Nelson, 2019). Don Mueller was given the title of "Godfather of Florida Olives" since he spent over 20 years tending to his 5-acre olive grove near Marianna, Florida. Mueller was able to see his olives bloom and produce, and with his careful cultivation and engineering skills, he built an olive mill specific to his needs. He even entered an international olive oil competition and was awarded a gold medal (Florida Olive Council, 2020). It is critical to note that higher oil yield is due to proper irrigation; researchers found that irrigated olive trees averaged 30% more oil than non irrigated trees (Fereres, et al., 2003). With olive production comes sustainable management and sustainable irrigation practices that significantly impact the quality and quantity of the grove's overall production. Olive trees do not bear fruit regularly or often do not bear a similar fruit year after year. Therefore, proper and sustainable irrigation practices can control alternative bearing throughout the year, so long as there are no reported weather issues. The Florida Olive Council follows the concept of early irrigation to support shoot growth, increasing the average fruit for the following season (Florida Olive Council, 2020). Additionally, surface water or water from dams and rivers is primarily used for irrigating olive groves in Florida, depending on water quality.

Meanwhile, in the Middle East, specifically Jordan, Palestine, and Israel, olive trees are rain-fed, and when drought becomes a risk, proper irrigation techniques are put into place. However, the people of Palestine have limited access to water resources due to them being under Israeli Military Control. Therefore water pools that collect rainwater in winter to be used in summer are their primary water sources for irrigation in the summer months (Oxfam, 2010). In Israel, olive trees are mainly non irrigated slow-growing but grow to a canopy that can carry commercial crops. However, with high production comes high water stress in the late summer months, which could cause nonsequential maturation and shriveled fruit (Lavee, 1990). Utilizing irrigation, Israel can use its "hard water" or high mineral content water for irrigating groves being used for intensive olive farming (Lavee, et al., 2007). In Jordan, most olive trees are planted in rainfed areas, where rainfall requirements must exceed 300 millimeters, while others are planted on well-irrigated land (Alhairy,

2018). With that being said, Jordan hugely lacks in water resources, having a per-capita share of fresh water at less than 100 m3 year-1 (Aquastat, 2019). Irrigation as a practice in Jordan absorbs almost three-quarters of the country's freshwater resources. Therefore, Jordan has had to mitigate by producing with less irrigation through maximizing water productivity. Implementing deficit irrigation has proven substantial in increased agricultural production across the board in areas of water stress. Deficit irrigation (DI) is the act of supplying crops with water below their total requirement (evapotranspiration). This technique allows water-scarce areas to reduce their irrigation use and maintain sustainable water management practices (Fereres, et al., 2006).

With olive trees being known for their resiliency, deficit irrigation does not allow for long-term adverse effects; some researchers have found that this technique has even increased oil quality (Naoum, et al., 2018).

Suppose proper attention is not placed on siting, species, cultivation, and irrigation; in that case, olive groves could suffer from permanent damage, which will be costly to farmers and potentially the ecosystems if water is wasted. On the other hand, when using proper water stress mitigation practices and sustainable water techniques, the olive groves will prosper, crop yield loss will be prevented, and reduce the cost of water, especially during droughts.

1.2 Problem Statement

The Florida Olive Council is one of the leading resources for Floridian farmers to refer to for answers regarding their olive cultivation. The council provides information on irrigation practices that could benefit farmers, including irrigation supplies and maintenance techniques (Florida Olive Council, 2020). However, literature on the history and cultivation requirements of olive trees in both Florida and the Middle East has not shown any prior research on irrigation best practices that put both regions alongside each other in a method of comparison. Therefore, this study will compile best practice techniques and recommendations for changes moving forward in the olive cultivation industry.

1.3 Objectives

- Assess the current system in Florida and the Middle East in terms of irrigation of olive groves.
- Compare water stress mitigation strategies from the Middle East to Florida.
- Investigate possible best practices from the Middle East to be used in Florida.
- Develop recommendations for both the Middle East and Florida to create a more sustainable olive grove cultivation.

1.4 Research Questions

- What irrigation best practices are being used for olive cultivation in Florida, Jordan, Palestine, and Israel?
- How do Florida, Jordan, Palestine, and Israel deal with water stress during dry seasons?
- How could best practices from the Middle East be transferred to those in Florida regarding olive tree cultivation?
- What effect would best practices from the Middle East have on olive groves in Florida and vice versa?
- What forms of sustainable water management practices could be learned from the US to the Middle East for high water stress periods?

1.5 Significance of Study

This study is relevant as olive grove production in Florida is still young, there is enough time for advancement, and the goal here is for this paper to be used as a fact form for those in the field. This study will highlight efficient and sustainable olive grove production, maintenance, and olive oil production techniques in the Middle East. The state of Florida could update local efforts to mirror first-hand accounts from those working in the field in Jordan, Palestine, and Israel, especially in terms of supporting cooperatives and communities through the triple bottom line; the Middle East is a classic example of that.

Ways to conserve water abroad are very creative since dry spells, wars, and of course, climate change hit the Middle East a lot harder than those in the US have

seen. A compiled list of methods and ways to conserve water will positively serve those in the US and Florida. It will help prove that sustainable and diverse water practices will help eliminate the conventional and often wasteful water methods that are being used now.

Since those in the Middle East rely heavily on the profit from their crop, a good crop every year is very important for their well-being. Therefore, allowing them to ensure a healthy and prosperous crop yearly could benefit farmers in the US. Additionally, farmers in the Middle East often rely on organic fertilizers; this will help encourage the end of using roundup under trees and instead allow for more organic and more sustainable fertilizers to be used that will eliminate any damage. Roundup is the commercial name for the herbicide known as glyphosate; the use of this herbicide has been controversial for many years since it acts to eliminate weeds while at the same time deters plants from producing proteins that are essential for their survival (Wilkerson, 2015).

1.6 Scope of Study

Florida is being analyzed in this study since it moved its agricultural focus from citrus groves to olive groves due to a disease called Citrus Greening that began in Florida in 2005 and crippled the industry (Florida Citrus, 2018). Jordan, Palestine, and Israel are being highlighted here for opportunistic reasons since the researcher is from the region and has connections in the field that will be utilized for the success of this study. The study will strictly assess current practices in both the regions (the US and the Middle East) in terms of olive cultivation, irrigation, and water sustainability. Combining these two regions in this study will allow the reader to follow both historic practices implemented in the Middle East and new and improved innovations concerning olive cultivation and maintenance.

The scope of the study will focus on irrigation best practices in both regions, as well as water stress mitigations and sustainable water resource management. Following that, best practices for quantity and quality of olive production in Florida, Jordan, Palestine, and Israel will be emphasized.

2. Literature Review

2.1 Olive Trees and Irrigation

University of Florida's Institute of Food and Agricultural Sciences (UF IFAS) describes olive trees as one of the most ancient cultivated crops known by its botanical name Olea Europaea. Various types of olive trees exist on this earth; however, the European olive tree is the one to invest in if the long-term goal is to use its fruit for oil production (IFAS, 2016). According to recent research, more than 90% of olive trees are grown for oil production. This oil is used in the cosmetics industry and pharmacy and textile industry (Carr, 2013).

The olive tree is a desert tree known for its resilience, ability to grow in any place, and requires almost no water. However, to cultivate a fruiting tree for an economic value, the olive tree must be irrigated, utilizing rainfall or traditional irrigation. As researchers have noted in the field, identifying water requirements for olive trees is a difficult task. Water requirements depend on location, tree variety, age, and soil properties (Fereres, et al., 2011). Extensive research has been conducted to estimate irrigation scheduling based on the reaction of olive trees, which were initially rain-fed and now are connected to an irrigation system. This research method requires the monthly calculation of components related to tree transpiration and water evaporation. Nevertheless, it is not a method applicable to all tree situations; therefore, research on general water requirements is still being conducted (Testi, et al., 2005). Nevertheless, based on experience, Middle Eastern farmers have created watering schedules specific to their dry and wet months; this can be seen in Table 2.

Economic value comes from the quantity and quality of the fruit-bearing olive tree; the better the irrigation, the more consistent and manageable it will be. Landscape considerations must be set when intending to grow a fruiting crop; interesting enough, the olive tree can succeed in poor soil since excessive fertilizers packed with nitrogen could cause weak shoot growth, which would then affect the fruit, as well as light and free-draining soils (IFAS, 2016). Drip irrigation has shown farmers the actual benefit of irrigation, a major one being the increase in plant densities. Irrigation is generally necessary to go hand in hand with low summer rainfall. Additionally, most countries cultivating olives struggle through water stress,

allowing farmers and researchers to experiment using deficit irrigation mechanisms. Deficit irrigation has been executed in Spain, Jordan, and elsewhere (Carr, 2013).

2.2 Olive Trees in Florida, USA

The State of Florida's soil and the weather are comparable to that of the Mediterranean Basin, which allows it a significant advantage in terms of olive cultivation. As of October 2020, the state has an average of 800 acres of olive trees, in 20 of its counties being maintained by almost 80 individual farmers. This total amount of trees is a combination of both high-density commercial acres and backyard plots. With that said, Florida is facing a challenge in cultivating olives that could produce a commercial-grade crop; the state requires a species that can adapt to lower latitudes -- for olive trees to prosper and bloom in the spring, they must accumulate 300 - 400 chill hours in the winter, chill hours are one hour at a time between 32 and 45° F (Garcia, 2020). To find a solution, the Florida Olive Council has been conducting an extensive search to find olive cultivars that would be able to survive Florida's temperature -- their focus has been on the Middle East and North Africa region (MENA), Southern Australia, and South America. As a result, researchers with the Florida Olive Council have seen newly grafted trees bloom Spring of 2021, noting that the sunny side of the tree is where they observed the bloom (Florida Olive Council, 2020).

The University of Florida IFAS extension has a descriptive guide on the necessities of a prosperous and financially productive olive crop; nutrition, irrigation, tree variety, location, and pest issues are all high priority concerns (UF/IFAS, 2020). Well-drained soil is an essential requirement for establishing olives anywhere; avoiding areas with standing water or accumulated water after rainfall rotted roots are also avoided, and healthy cultivation is expected. IFAS researchers also stress the olive tree's low nutrient requirement, noting that Florida's most significant challenge with olive cultivation will be excessive fertilization and water (Thetford, et al., 2018).

2.2 Olive Trees in Jordan

Researcher Brittany Cook in her 2018 dissertation titled "Producing Traditional International Standards and Development in Jordanian Olive Oil," described Jordan,

like many other Middle Eastern countries, where olive trees and oil are seen as holy and blessed. Olive trees are critical to complementing local food and stimulating the economy. These trees are so crucial to the country and its people that it is illegal to uproot centennial olive trees without a government-issued permit. With that said, Jordanian olive oil production is mainly to be used and sold internally within the country; it is estimated that about 98 percent of Jordanian olive oil production is consumed locally (Cook, 2018). In Jordan, 72 percent of agricultural land is covered by olive trees; the Jordanian Department of Statistics in 2018 report noted that this sector alone created job opportunities and stability for more than 80 thousand Jordanian families (The Jordan Times, 2018). During a water project in 2016, USAID noted that water supply levels began to decrease and groves in the region started to wilt. Water bills were high due to the use of freshwater for irrigation and livestock hydration. During this crippling time for farmers, organizations like USAID and Mercy Corps funded and encouraged drip irrigation systems for households and a water recycling tool that would reuse greywater (USAID, 2016).

In a study titled “Productivity of water, growth, and yield of olive trees under deficit irrigation,” the researchers described deficit irrigation as a highly efficient practice for an area like Jordan. This practice would be successful since Jordan is not a country surrounded by water resources; resulting in water stress, the lack of freshwater resources has been one of the critical constraints to the country’s agricultural development (Naoum, et al., 2018). However, there are still practices that could allow Jordan to produce more with less water; this would be through a technique that would increase crop water productivity. Producing more with less water could be implemented through Deficit irrigation (DI) since olive trees can withstand and recover from minor water stress complications. Additionally, it has been proven that water stress has a positive effect on oil quality. Researchers monitored the “Effect of water stress on super-high-density ‘Koroneiki’ olive oil quality,” the researchers concluded that water stress through deficit irrigation lowers free fatty acid content, which directly results in higher quality oil (Dag, et al., 2014). Research done on olive groves in the Northern highlands of Jordan during 2012 through 2016 shows that deficit irrigation practices would save water and maintain the olive tree yield (Naoum, et al., 2018).

2.3 Olive Trees in Palestine and Israel

In Palestine, olives and olive oil have a significant influence on the economy; olive harvest season begins from early October until early November where Palestinian families and cooperatives come together to fuel the country with its liquid gold. Once picking has been completed, olives are sent to the press, pickled, or cured for the table. As published by Oxfam, a global organization that works around the world to end injustice and poverty, in a report titled “The Road to Olive Farming” in 2010, almost 45 percent of Palestinian land in both the West Bank and the Gaza strip is covered with olive trees, more than 10 million trees that could produce an average of 34,000 metric tons of olive oil during a productive and prosperous year (Oxfam, 2010). Furthermore, Palestinian olive cultivation is known for its sustainable production and low environmental impact due to organic fertilizers like cow manure instead of chemically derived fertilizers. In addition, Palestinian farmers use soil tillage to improve soil productivity; this activity eliminates weed growth and destroys pests and the physical condition of the soil.

A journal entry titled “Using Non-Conventional Water in Irrigation of Olive Trees and Its Effect on Olive Oil Properties” highlights the political conflict in Palestine and the restriction on water that has resulted because of it. Additionally, the researchers also mention the effects of climate change and the exploitation of available water resources on Palestinian food security and water resources. However, the gap created as a result has been in the mitigation by Palestinian farmers through utilizing non-conventional water resources, in this case, wastewater and saline water for crop irrigation purposes. With treated wastewater effluent, sustainable water resource management will coincide with other sustainable techniques utilized by Palestinians, like organic fertilizers. Additionally, treated wastewater effluent is low in cost and is a source of nutrition for fertile and productive soil (Barghouti, et al., 2017).

In Israel, updated and cost-effective irrigation practices have played a vital role in the sustainable advancement of its agricultural sector. For example, Rivulis is a company that provides micro-irrigation solutions for farmers. In Israel, the company installed micro-irrigation on an intensive level for commercial farming. Micro-irrigation is a form of low-pressure and low-flow-rate irrigation that allows for the potential of

overwatering (EPA, 2020). As described by their researchers, the results of this project were successful; since water for irrigation was now at a lower cost, there was more profitability for the farmers. In addition, Rivulis researchers engaged all sustainable techniques; this included a recommendation on future planning to maximize the number of seedlings being cultivated (Rivuliss, 2019).

2.3.1 Olive Tree Varieties in Palestine and Israel

Fourteen olive tree varieties exist in both Palestine and Israel. Below are variations of olive trees that have been highlighted across different scholarly sources. Souri and Shami varieties are of Lebanese origin; in warmer regions, this variety is known to ripen during October; in colder areas, it matures in November, and fruit generally can remain on the tree until January. Additionally, Souri or Shami trees are known to be resistant to insects (Wafa, 2021).

However, many olive trees worldwide are often affected by Spilocaea Oleagina, also known as olive peacock spot, a fungal disease that can generally cause delays in ripening and reduce olive oil yield. Therefore, researchers and agricultural specialists have concluded that consistent and persistent annual fungal treatments on olive trees could reduce future infection rates (Teviotade, et al., 1995).

Nabali Mohassan is not a local variety known to Palestine. However, it is found in the highlands of Hebron and Bethlehem, recharacterized as a variety of rapid vegetative growth, primarily when seedlings are derived from rooted cuttings. This variety blooms many months before the local type known as Nabali Baladi; this means the crop can hold its crop yield longer during suitable weather conditions. In addition, this variety responds to rainfall, irrigation and is very responsive when watered.

Nabali Baladi is a local early ripening variety known to the outskirts of Jerusalem all the way to the City of Nablus in the West Bank. The Nabali Baladi has a broad vegetative complex known to commercially fruit in its eighth or ninth year while growing on rain-fed lands.

Other varieties that are not as known include K18 or Barnea, known for olives used for mass production of pickled olives, Manzolino, Arbequina, Jebbah 1 and 2,

Malouk, Bekool, Askal, Mehavia, Rasei, Rasesi, Malisi, Barri, and Chemlali (Wafa, 2021).

2.4 Soil Characteristics in Florida and the Middle East

2.4.1 Florida

Myakka fine sand, the official soil of the State of Florida, is unique to its acres of Flatwoods. Myakka sand is known for its sandy and wet properties, making it a somewhat poorly drained and acidic soil stained with low organic and fertility content (Florida Department of State, 2021). When Myakka sand is close to shell deposits or the beach, its properties become more alkaline (the opposite of acidic). Therefore, these areas should be avoided when deciding on olive tree cultivation since this type of soil does not allow for proper water drainage, killing the tree (Olive Oil Source, 2021). Agricultural specialists and soil experts have highlighted limitations since poorly drained, and acidic soil generally requires modification to create controlled acidity and water levels for successful agrarian use. In Florida specifically, the months between June and October are considered the rainy season (Zahng, et al., 2017). The rest of the year is when drought and extremely dry spells are awaited. Therefore, water control systems are recommended for farmers to save water during the rainy season and irrigation technology during the drought season. Wind erosion is the second limitation that must be considered when planning any agricultural practice. Due to the soil's sandy characteristics, a strong wind could cause low soil levels, a major agricultural disadvantage. The solution to wind erosion would be proper planning during the initial stages and planning for a windbreak that shelters any crop from damaging winds. Finally, nitrogen and phosphorus discharge from sand is expected to harm groundwater quality by contamination (Soil Science Society of America, 2013). The Florida Department of Agriculture sets up nutrient management best practices for agricultural fields to minimize any adverse effect on water resources (Florida Department of Agriculture and Consumer Services, 2021). These best management practices include but are not restricted to testing water, soil, and plant tissue near and around the growth area, managing cultivation with efficient fertilizer and leaching application -- and finally avoiding mismanagement of fertilizer during transportation, storage, and use (Mission Resource, 2021).

2.4.2 Middle Eastern Soil Conditions (Jordan, Palestine & Israel)

Typical soil conditions that have historically hosted mass olive tree cultivations in the highlands of the Middle East region are many; shallow clay loam soil, non-cracking soil, and cracking clayey soils. These soils are calcareous and contain levels of limestone. However, they lack the needed levels of nitrogen, phosphorus, iron, and manganese. The ground in the highlands of the Middle East where olive trees specifically can grow is known for its heavy texture that can hold water in higher capacities -- which then allows for the absence of supplemental irrigation during winter or rainy months (Al-Jaloudy, 2015). The soil in Jordan, Palestine, and Israeli highlands are similar due to the geographical terrain. This loam and clay loam soil has been proven adequate for successful olive tree cultivation since it allows for proper aeration of solid root growth. Additionally, the resiliency of the olive tree provides for it to tolerate various chemical levels and qualities. However, farmers and agricultural specialists should monitor and maintain moderate to moderately basic soil pH levels (higher than five or lower than 8.5) (Olive Oil Source, 2021).

2.5 Rainfall

2.5.1 Average rainfall in the State of Florida

As confirmed by researchers affiliated with the University of Florida's IFAS extension, rainfall in the State of Florida comes between June and October -- with an amount that ranges from 40 to 60 inches per year depending on the specific geographical location in the State. Rainfall in the State is also known to be spatially variable, caused by thunderstorm patterns making it rain on one side of the street but not the other (Zahng, et al., 2017). With an average annual precipitation of about 54 inches across the entire state. In Florida specifically, a difference in rainfall amounts can be seen between its Northern and Southern regions. There is a significant difference when comparing drought months and wet months, as confirmed by the Florida Climate Center of the Florida State University. From Tampa to Key West, these cities average 1.5 to 2 inches of rainfall during their dry months between November and April. However, from Tallahassee to Daytona Beach, average rainfall has been observed between 2.11 and 4.18 inches during their wet months between September and June (Florida Climate Center, 2021).

2.5.2 Average rainfall in Jordan, Palestine & Israeli Highlands

In Palestine and Israel, as reported by Fanack Water, Palestine there are different transitional climates, from Mediterranean climates to the most extreme of desert conditions. Rainfall is explicitly limited to the wet months of the region, which are confined to winter and spring months, almost the total opposite of rainfall conditions in Florida. Between October and April, rainfall averages between 450 and 500 millimeters per year (about 20 inches per year) in most Mediterranean climates of the region. While in the most desert conditions in Jericho and the Jordan Valley, that region averages 145 millimeters of rainfall per year (about 6 inches) (Fanack Water, 2015).

According to the Ministry of Foreign Affairs of the Netherlands, when reporting on climate change in the Middle East, Jordan is described to have three different climatic regions. First, the Jordan Valley that borders Jericho in Palestine gets an average annual rainfall of about 150 millimeters per year (6 inches per year). Second are the Jordanian highlands, which extend from the utmost North to the furthest point south of the country, known to have an annual rainfall of 600 millimeters per year (about 26 inches per year). Finally, the desert region of the county, where average annual rainfall is as low as 50 millimeters (2 inches) (Ministry of Foreign Affairs of the Netherlands, 2018).

2.6 Olive Tree Specific Chill Hours

Based on the University of Florida's IFAS extension research, for olive trees to be in good health, they must be nurtured in an ideal environment, including but not limited to climate. Climate, specifically in Florida, is one of the most significant challenges to control, flooding in the rainy season, extreme drought in the winter, and considerable humidity year long. Chill hours are described as hours of cool temperatures (between 32 and 47 degrees Fahrenheit) that allow for floral buds on olive trees. This time is critical for the tree's life cycle since these metabolic changes that are unseen are the reasoning for a flourishing tree during the spring months. Since an olive tree could die if temperatures fall below 10.5 degrees Fahrenheit, an olive tree's future success could be hindered if temperatures drop below 22 degrees Fahrenheit. Researchers have concluded that if temperatures are not ideal during

the new growth period, which is about 29 degrees Fahrenheit, the optimal future success of the tree could be completely obstructed (Byron, et al., 2019).

Michael Garcia of the Florida Olive Council states that since olive trees growing in Florida are of the European variety they require a similar amount of chill hours as found in areas like Spain, Greece, and Italy, where chill hours are 300 plus (one chill hour equals one hour of temperatures between 32 and 47 degrees Fahrenheit). He does include that olive trees are known to adapt to different climatic environments over time. However, the initial phase is the most critical, and farmers should adhere to this if they wish to have a profitable crop (Garcia, 2018).

3. Methodology

This study is an international comparative case study of sustainable olive production focusing on irrigation and sustainable olive grove management, including a mixed-methods approach of primary and secondary data collection. The primary data collection includes qualitative research in semi-structured interviews with key stakeholders from both regions and participant observations, and a site visit of The Olive Grove in Brooksville, Florida.

In this study, experts in sustainable agriculture and olive grove farmers have provided expert advice and answers to predetermined questions on the possibilities of sustainable olive grove production and sustainable irrigation methods, including methods on irrigation during dry months. In Florida, three farmers were interviewed, Dede Rizzo, the owner of the Olive Grove in Brooksville, Florida, where she maintains over three hundred trees of nine different varieties -- along with her olive press (The Olive Grove, 2021). Lynn Dettenmayer, owner of the Jefferson Olive Groves in Jefferson County in North Florida, where he and his wife Pat maintain 300 olive trees of the Arbequina and Korieniki variety (Jefferson Olive Groves, 2021). Lastly, Michael Garcia, President of the Florida Olive Council, was interviewed extensively since the council is a non-profit research center that focuses solely on agricultural practices that could promote a successful and sustainable olive grove industry in the State of Florida (Florida Olive Council, 2020). From the Middle East, initially, an exploratory interview with Nada Majdalani was conducted.

Majdalani then referred to Kassim Abdo, freelance agriculture, climate change, water, and environment consultant. In the past, Abdo was managing the agriculture export division of the Palestinian Ministry of Agriculture. Currently, Kassim is working with farmers in the West Bank city of Nablus on a wastewater reuse project to be used on olive groves. Next, Asad AlKhader was interviewed from Jordan as he specialized in soils and irrigation, with a Ph.D. in horticulture, crop science, and plant nutrition. Finally, farmers from Palestine were asked the questions found in Appendix 1 through Rami Massad, who is an agricultural advocate and has been working with Palestinian farmers who have experienced violence since olive trees are at the forefront of the ongoing battleground between the Palestinians and Israelis to the ongoing occupation of Palestinian land, and Israeli settler violence (Ibrahim, 2019).

3.1 Data Collection

3.1.1 Interviews and Literature Review

By utilizing the interview method, information was gathered from professionals in the field and considering their olive cultivation experience in Palestine, Israel, and Jordan via email and phone conversions. In addition, experts who were working in olive cultivation in Florida were included by planning site visits and phone conversations. Scope of time did not bear any significance for this research as the knowledge and information being incorporated has developed over time, and advancements from these professionals can be included as knowledge learned over time. A literature review was then incorporated into this section to define and investigate terminology and techniques mentioned by the experts. It was critical to include a literature review in this section, as many concepts mentioned by the experts needed further clarification and evidence to prove relevance.

The Palestinian director of EcoPeace Middle East, Majdalani, discussed cross-border knowledge exchange between Jordanian, Palestinian, and Israeli environmentalists, specifically on olive groves. Majdalani discussed risk management best practices, climate change, and early warning systems connected to the three countries. Majadalani also expanded on the Jordan Valleys' shift from citrus cultivation to date palm due to climate change and access to water. Date palm,

similar to olive trees, is resilient to dry weather spells. Ending the interview with a question, Majadalani asked: how would systems create incentives for communities to deal with droughts (Majdalani, 2021).

On May 19th, 2021, a site visit was organized to The Olive Grove in Brooksville, Florida, where Dede Rizzo gave a tour while answering the questions provided in Appendix 1. Since the tour was in person, the answers to the questions were met with a visual representation of the trees themselves. Especially when asked about the varieties, Dede walked straight to the tree and explained its type, needs, strengths, and weaknesses since all cultivated trees were planted over five to seven years ago. The tour was recorded and then manually transcribed. On May 29th, Lynn Dettenmayer of the Jefferson Olive Groves was interviewed via phone. Dettenmayer was asked a series of questions, and the answers again were recorded. Finally, Michael Garcia, President of the Olive Council, was able to share more than answers to the interview questions but shared publications and research papers that he supported during the past few years that focused on irrigation, chill hours, and pest control which have been included in the body of this research. These interviews aimed to seek information on opportunities and challenges of olive cultivation in Florida, their irrigation methods, fertilizer, and other maintenance techniques that the experts can share.

For those in the Middle East, phone conversations were planned regarding time zones; all interviews were in Arabic, recorded, transcribed, and translated. The same set of questions in Appendix 1 were translated to Arabic and then emailed to Rami Massad, who was then able to ask farmers in Palestine's field. Since the climate in all of Jordan, Palestine, and Israel are similar, answers to specific questions have been generalized to cover the three countries as getting in touch with additional farmers has been difficult due to the instability in the region.

3.1.2 Thematic Analysis

The interview questions were then analyzed using thematic analysis methods; by attempting to find common ground between the answers, this was conducted by manually highlighting similarities between the transcribed responses after the interviews were finalized. The main goal here was to find patterns that the farmers both in the Middle East and Florida agree on, what they disagree on, and then

highlighting points that either of them has yet to discover for the success and sustainability of their olive groves.

4. Results

The semi-structured interview questions began with asking about the initial phases of olive tree planting, prepping process, location, and variety. The farmers and agricultural specialists responded to the best of their ability; additional information was obtained from the University of Florida's IFAS extension, where most research on olive trees in North Florida is being conducted. Additionally, journal articles and other published literature on olive trees, olive tree irrigation, and olive tree cultivation were applied.

4.1 Planting Location and Soil

Rami Massad asked multiple Palestinian farmers in villages surrounding the West Bank their initial strategy when growing new olive trees. The response was quite simple; the farmers stressed significantly how critical the initial years are on the sustainability of the tree in the long run. To begin, the farmers plow, clean, and prep the land for the seedlings or tree cuttings -- digging no less than 60 - 70 cm (23 - 27 inches) for each tree. An important consideration is that the holes being dug out are expected to remain open for 20 days before planting so the sun can act as a sterilizer (Massad, 2021). Soil sterilization is critical to limit plant species, pests, viruses, fungi, and other bacterias in the soil that could negatively affect the olive tree and destroy the crop in its entirety. Soil sterilization could be done through chemical and traditional sun exposure or "heating" processes (O'Malley, 2001). The farmers accentuated the need to plant olive trees by variety and not mix varieties close to each other for cross-pollination. When trees of different varieties are mixed, factors like blooming time and viable pollen could affect pollination. However, this could be avoided when trees of the same type, bloom time, and pollen viability are close by (Chaney, 2021).

Dede Rizzo from Brooksville, Florida responded with an example; she mentioned that during her initial research, she places the same variety in two different locations on her property, one near an oak tree and another near a pine tree. Five years later, it is evident that the olive tree that was rooted near the pine

tree grew much quicker, much larger, and held crops due to the level of acidity in the soil. Meanwhile, the olive tree that grew next to the oak tree is barely half the size it should have been after all those years (Rizzo, 2021). Though Dede Rizzo mentioned that this could result from pH levels, Kassim Abdo said that it results from the root structure of the two trees (Abdo, 2021). Based on Martin Dobson of the Arboricultural Advisory and Information Service research, pine tree roots are shallow, growing only 12 inches under the surface, while oak trees are known for having tap roots, which spread over 90 feet from the tree trunk (Dobson, 1995). This observation is critical since disturbances in the soil while an olive tree is in its phases of growth could cause damages to the roots the tree is forming; this has been observed at the Rizzo grove where the olive tree that is near the oak tree is much smaller and unable to bear crop as it is weak.

Meanwhile, Lynn Dettenmayer tested the soil all around his 77-acre plot of land in North Florida. Results showed that the soil was a mixture of sand and orange clay or bird soil, a type of loam soil. Having soil that is not as highly sandy as found in counties South of Florida, that does not have water retention properties, and clay soil as located in Georgia, Dettenmayer found himself at an advantage with adequate soil conditions for his soon-to-be olive grove (Dettenmayer, 2021). Asad Alkhader, Jordanian soil, and irrigation specialist highlighted the required properties of soil for prosperous olive trees; stating that soil pH is expected to be between 5.6 and 5.8, soil depth is to be between 0.1 and 5.1 meters, and the percentage of sodium in the soil should be less the 15%. In addition, AlKhader noted that an increase in sodium and magnesium in the soil would lead to the dispersion of soil particles, which would then lead to reduced soil permeability to drainage and airflow (Alkhader, 2021).

As for tree spacing, there was a consensus between those interviewed that the trees should be planted 10-15 feet apart; spacing out the trees is essential to maintain its canopy without having to intertwin with other trees nearby. In addition, trees must have access to full sunlight; proper spacing between trees averts a situation of harmful shadowing, which then affects crop yield. Finally, for Florida specifically, spacing is critical for airflow due to the high humidity level the state experiences year-round.

4.2 Climate Conditions

Weather conditions suitable for olive trees are a critical component to be investigated -- Dede Rizzo noted that Brooksville, Florida, did not experience harsh weather conditions like the rest of the state since she started her olive grove. She mentioned that winter frost has come around her olive grove but had no significant effect on her trees (Rizzo, 2021). Meanwhile, Dettenmayer had a different experience with winter in the northern part of the state. In 2017, Florida winter was considered the coldest the state has seen in years; coincidently, it was the year Dettenmayer planted his first 300 trees. Unfortunately, soon after planting the trees, the cold winter killed more than 20% of the newly planted olive sticks (Dettenmayer, 2021). Similarly, Michael Garcia, during the interview, referred to hurricane Irma, which hit the Florida religion in 2017, that damaged over 200 olive tree grafts of different varieties (Garcia, 2021).

As described by Asad AlKhader, relative air humidity suitable for olive trees is between 40 and 65% in the Middle East, which in this case, the range of humidity in Florida is close to 80%, which could be detrimental to the olive if the spacing is disregarded when planting the trees as mentioned earlier. Nevertheless, prosperous olive trees are attainable in Jordan, Palestine, and Israel since year-round humidity does not surpass 65% in mountainous and semi-coastal regions where olive trees are mostly found (AlKhader, 2021). Furthermore, others interviewed in the Middle East had no reported weather issues regarding a negative effect on the crop or its production.

4.3 Fertilizer and Pest Control

Based on research conducted by Paul Vossen, a University of California Farm Advisor, olive trees succeed in conditions of low to minimal nutrition. Vossen's study on the fertilizing of olive trees states that the olive tree does not starve even in the poorest of soil conditions. However, the olive tree will respond positively to an appropriate irrigation system that allows for its continuous hydration, along with proper soil and spacing to avoid root competition (Vossen, 2007).

During the interviews with Florida olive farmers, there was a mixture of food additives and fertilizers on their trees. Dede Rizzo mentioned that she fed her trees

potassium about twice a year, which is known to increase leaf area. Rizzo has not yet identified pests in her grove; no necessary actions have been taken in this regard (Rizzo, 2021). In contrast, Lynn Dettenmayer mentioned that no fertilizers are needed due to the high-quality soil in his fields. However, he has in the past been forced to use herbicides out of necessity; before having to give in to the use of chemical herbicides, Dettenmayer attempted to use flame weeding, a technique that is highly effective at killing and eliminating weeds. However, he could not eliminate weeds in his grove using this non-chemical method (Dettenmayer, 2021).

Meanwhile, farmers in the Middle East were strict in their views since their techniques have been passed down from their ancestors hundreds of years ago. Based on the information Rami Massad was told by farmers from Palestinian villages that fertilizer is not recommended for olives during its first year of having been planted, once the roots are firm in the ground, that is when compost and cow manure is to be used around the olive trees (Massad, 2021). With nutrition being less important than water, adult olive trees require fertilizer or compost once or twice a year during the rainy season to avoid the concentration of utilized fertilizer in certain areas versus others (Vossen, 2007).

Researchers associated with the University of Florida IFAS extension identified occasional pests in Florida, as seen in Table 1 (Gillett-Kaufman, et al., 2014). Additional pests are included in the table to mirror information received from farmers and agricultural specialists that were interviewed.

Table 1

Pests found on Olive Trees in the Middle East and Florida.

Pest	**Effects and Mitigation Strategies**
Stink Bugs "Euthyrhynchus floridanus."	This bug feeds off other plant pests, like beetles and caterpillars, and does not cause any noticeable damage (Garcia, 2021).
Leaffooted Bugs	These bugs attack the olive tree yield and could cause significant damage if not monitored. When

	trees are affected by this bug, parasitic flies, and stink, bugs could be introduced to manage the infestation (Gillett-Kaufman, 2014).
Glassy- Winged Sharpshooters	Native to Florida, this pest feeds off of olive trees -- once the leaves turn brown, a rapid decline of the tree's health is expected. Farmers who can identify this pest are expected to call their local agricultural commissioner's office (IFAS, 2021(Gillett-Kaufman, 2014).
Soft Nose - "Olive Anthracnose"	Olive yield in the Florida panhandle has been targeted by this fungal pathogen caused by warm, humid conditions when the fruit ripens. The treatment for this fungal infection is a calcium spray; it is recommended to be used during early summer to combat it and not manage it (Garcia, 2021).
Peacock Spot/Eye	This is a fungal disease that affects the leaves of the olive tree; as the leaves begin to die, they fall off of the tree, which then works to weaken its crop yield. The treatment for this disease is excessive pruning, which helps with the rejuvenation of the tree through the creation of additional space to allow for accessible air and sun (Massad, 2021).

The University of Florida IFAS Extension has identified many other threats to the olive trees that are not native to Florida and do not show up often. Additionally, the type of treatment or pesticide use, as noted by Michael Garcia, depends on organic or non-organic farmers (Garcia, 2021). As Dennis Patton, a county horticulture agent, explains, pesticides could be created in a lab or extracted from natural resources, which labels farms as organic and non-organic. All pesticides eventually kill pests. The difference between organic and non-organic is the chemical

breakdown of the product being used (Patton, 2019). Organic products, however, break down quickly, which means their protection span is shorter-lived, and reapplication is then required.

When discussing pests, Lynn Dettenmayer said that in the past ten years, since he planted his olive trees, he has not found the need to use pesticides. However, Dettenmayer mentioned that he was forced to use herbicides out of necessity after many attempts at hoeing his land with no success at killing the weeds. Before resorting to Roundup, Dettenmayer bought a propane flame thrower that failed to stop the weeds (Dettenmayer, 2021). Roundup or glyphosate is a herbicide sprayed onto the soil to kill weeds and grasses that compete with other crops and could cause damage to them. The use of Roundup has been part of a controversial conversation since it has been discovered that the toxins being sprayed into the soil transfer into the crop yield and could increase the cholesterol levels in consumable products (Caballero, 2021).

Columnist Adris Higgins with the Washington Post joined the conversation and highlighted effective and sustainable weed-killing remedies that fellow farmers could adopt in Florida and the Middle East. Higgins begins with the basics, taking a step back and assessing the land in general. Are problems like poor drainage or excessive shade times arising?. Solarization, the use of heat to kill weeds, is next on the list. This process is simple, using a plastic sheet to trap heat in the soil, eventually eradicating weed seeds from the soil. To support this claim, Sonja Birthisel, a scholar of weed ecology, points out that the process of solarization takes between two and twelve weeks, depending on the type of weed being tackled. Birthisel also mentions that soil microbes may be at stake during this process. However, these microbes like bacteria, fungi, and nematodes can return by restoring the soil with nutrients once the process of solarization is complete (Higgins, 2019).

4.4 Watering Methods

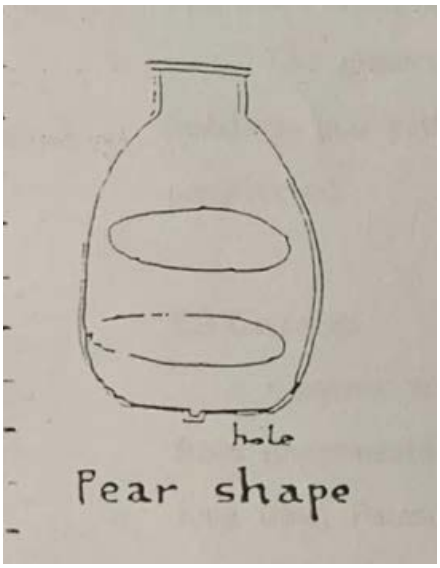
Assad Khader from Jordan pointed out that irrigation plays a vital role in dry areas like the Middle East, especially in areas of well-drained soils that have limited water storage capacity. Irrigation is essential for high-intensity crop fields (100-200 olive trees per Dunum or 0.25 acres) since hydroponic needs are extensive due to the dense vegetation and soil availability for each tree. Additionally, supplemental

irrigation is utilized during summer months or months of drought, which allows for increased production to up to 50%. Summer months in Jordan, Palestine, and Israel would be June, July, August, and September. If Floridian farmers considered supplemental irrigation practices, drought months would be between October 15th and May 15th. Jordanian farmers have found that irrigation allows for an early increase in production (starting the second year after planting). Irrigation has also proven to reduce alternate bearing, referring to the olive tree's tendency to produce a greater than average crop yield one year and a lower than average the next -- basically, irrigation would create more excellent stability for the farmer. Finally, irrigation allows for the increase in the percentages of pulp to pit ratio, or ratio endocarp to mesocarp in fruit, one of the most desirable qualities for table olives or for olives to be sent to the mill (Khader, 2021).

When discussing drought and summer months, Kassim Abdo mentioned the concept of pear-shaped rainwater harvesting wells in Palestine. These shallow wells function as rainwater harvesting systems independent of the water supply network, making the concept an ideal solution for water storage in rural and isolated areas. Palestinians have historically attached roof catchment systems to their homes and have discovered it to be the most appropriate system that allows rainwater to be directly stored in their wells. The construction of most cisterns or storage wells happened more than 50 years ago. They were initially pear-shaped, which reduced evaporation and controlled sediment of other materials into the well. However, as access to technology has increased, the wells are now being designed in rectangular or square shapes and go as deep as 5 meters (Abdo, 2021).

Figure 3

Pear-shaped rainwater harvesting well.



Note. This image was retrieved from a printed report titled “Rainwater Roof Catchment Systems from Household Water Supply” by Dr. Sufyan Sultan, Dr. Majed Abu-Sharekh, and Arch. Samar Nazer (1995).

During his interview, Michael Garcia showed agreement with Khader and Abdo, suggesting that it depends on the grove configuration; high-density operations should be expected to utilize drip irrigation, while conventional operations are often rain-fed. Pointing out that irrigation depends on many factors like tree density, variety, topography, and geolocation (Garcia, 2021). For example, Dede Rizzo, in her olive grove, uses drip irrigation, which she activates twice a day for forty-five minutes at a time during drought months. She mentioned that due to her sandy soil, and geolocation, rainy months had not affected the roots of her trees and that drip irrigation has been very beneficial to her olive grove (Rizzo, 2021). In his interview, Dettenmayer explained his olive grove watering process, which seemed like the least productive when considering drip irrigation and the reliance on rain. Dettenmayer strictly waters by hand by using a thirty-five-gallon water tank that watered his trees while on a tractor (gravity-fed) which usually takes him an entire day to water his couple of acres full of trees. During the interview, he expressed that he and his wife recently upgraded their system to a more efficient but still hand-watering method.

They bought a 300 by 1.5-gallon water tank on wheels equipped with a motor engine that then sprays their mature trees. When asked if irrigation would be something he would invest in in the future, Dettenmayer expressed that if he could go back in time, he would have included irrigation initially to save himself time and energy (Dettenmayer, 2021).

5. Discussion

After hours of discussion with farmers and agricultural specialists in the Middle East and Florida, it was concluded that water and irrigation were not the main issues at hand. However, Florida can gain extensive knowledge from the Middle East regarding its efficient irrigation practices. Since in the Middle East, water is generally an issue due to climatic and political issues. With water storage systems being one of the primary water sources for Palestinian farmers, water reuse and treatment could be a positive transition and best practice for them not only for olive groves but for agricultural purposes generally.

The farmers in each region had stresses that were much different than what was expected before initial research. For example, farmers in Florida stressed the importance of the variety of the olive tree on its resilience in the state. Olive tree varieties are being researched and tested in Floridian soils every year to expand on existing knowledge (Garcia, 2021). Additionally, pruning and other maintenance techniques are necessary for the tree's survival. However, Floridian farmers have expressed their lack of knowledge on the matter since their trees are still very young. Other random challenges were expressed by farmers in Florida, like damages caused to olive trees by deer at night; Dettenmayer discovered that by utilizing fish wire as a barrier, deer are less likely to cut through it and attack fruit-bearing trees (Dettenmayer, 2021).

5.1 Watering mechanisms

In terms of irrigation, Kassim Abdo noted that olive trees bear thirst, dry weather, and high temperature due to the nature of the leaves' composition that reduces transpiration, but the growth rate and yield decrease under these conditions. Furthermore, excessive irrigation leads to poor ventilation and rotting of the roots. Therefore, the rate of water absorption and the growth rate of trees decreases, and

the crop is affected, so irrigation must be provided to the soil to a sufficient extent between the field capacity (water remaining in the soil) and the wilting point (lack of water) to obtain an economical production in quantity and quality (Abdo, 2021). As shown in Table 2 below, Abdo provided a recommended daily irrigation amount of water (in liters) to be used on olive trees by age/years old and wet or dry month that Floridan farmers could adopt. Of course, when taking this into account, Floridian farmers should consider that the seasons between them and the Middle East are almost opposite. Drought months in the Middle East are in the Summer, while drought months in Florida are in the winter.

Table 2

Recommended daily irrigation amounts in the Middle East in liters by month and age of the olive tree provided by Kassem Abdo.

Age of tree by years	**Wet months**		**Dry months**		**Wet months**
	November and December	**October**	**April - September**	**March**	**Jan-Feb**
One year old	10L	20L	30L	20L	10L
Two years old	20L	30L	40L	30L	20L
Three years old	25L	40L	50L	40L	25L
Four years old	30L	50L	60L	50L	30L
Five years old	35L	60L	70L	60L	35L
Six years old	40L	70L	80L	70L	40L
> 6 years old	50L	80L	100L	80L	50L

Note. Provided by Kassem Abdo based on personal knowledge.

Similarly, UF IFAS researchers highlighted citrus irrigation scheduling which allowed for profitable tree growth and an increased crop yield without harming the

environment or water sources. When creating irrigation or water schedules, farmers and agricultural specialists will reduce the loss of nutrients in the soil by maintaining nutrients reaching the root zone from the irrigation system; this will ensure plant health and growth. However, the difference between the recommended daily irrigation schedule from Abdo and that of UF IFAS is that Abdo based this schedule on experience and positive annual growth. Meanwhile, UF IFAS based their citrus irrigation schedule on sensor technologies that can identify root zones, the measurement of soil moisture, and that at the same time can create water budgeting timelines that can lead to the ultimate success of the tree (Kadyampakeni, et al., 2017).

5.2 Maintenance techniques

During the interviews, there were growing concerns from Floridian farmers about pruning and general tree maintenance. Rami Massad was able to obtain techniques from farmers on the ground in Palestine. The farmers suggest that Floridian farmers take additional care of their olive trees during the initial months of planting, as they are the most crucial. Pruning is a vital maintenance technique that allows the tree access to sunshine; as new branches grow, old ones should be pruned. As the tree grows older and sturdier into the soil, pruning for production is necessary -- by forming layers that will allow the tree to take the shape of a solar umbrella (typical shape of the olive tree). With all other operations like plowing, soil turning, pruning, fertilizing, and irrigation active; the tree is only expected to succeed. Additionally, Massad confirmed that it is not recommended to plant other trees or crops in the same plot of land as olive trees as it is not necessary to create any type of challenge or competition underground for the olive trees' roots. However, planting medicinal herbs such as thyme and sage could be non-damaging incorporation since they do not consume much of the earth's moisture and nutrients that could be necessary for the olive trees (Massad, 2021).

Around the world, agricultural maintenance is similar; however, techniques and technologies have proven favorable to tree growth and crop yield. For example, in Australia, creating a healthy environment that supports the growth and development of the olive tree happens through calculated pruning, proper irrigation, and nutrition. The act of pruning is explicitly done to allow for tree training. Pruning

allows for the tree to take its shape from the moment its roots are established in the ground. This allows the tree to have sustainable and adequate ratios between its leaf to fruit, leaf to wood, and leaf to root, significantly affecting its overall production. Additionally, pruning is a critical component in the active growth of the olive tree. It promotes vegetative growth and steers the tree away from premature aging. Finally, pruning is essentially the act of opening up the tree; this allows for proper airflow, saving the tree from any pathogens that may prey on the tree if left wet with no air circulation. However, pruning is not an isolated technique. As mentioned earlier, other management practices like grove management must be significantly considered (Horticulture Innovation Australia, 2020).

6. Recommendations

This research study investigated current olive grove maintenance and harvesting best practices in Florida and the Middle East. Based on the interview analysis and literature review, this research study recommends the following:

6.1 Water Stress Mitigation

Water stress and drought are topics of discussion in both regions and have been for decades -- with that said, many mitigation techniques have been developed to allow for adequate water use without causing additional water shortages. For Florida, dealing with water stress and drought has been a constant struggle, especially since researchers declared that Florida is one of the many high-risk states that will suffer from a water shortage by 2050. With that said, local governments in the state have been advocating for systems that allow residents and customers to have access to adequate amounts of water for both personal and agricultural uses without excessive use -- this can be seen in the form of smart irrigation technologies (EPA, 2013). Additionally, Florida has had a leading effort in the water reuse arena. The states' desalination plant, located in Tampa, Florida, was the largest in North America before San Diego introduced its one billion dollar desalination plant in 2015 and took that title (Florida Department of Environmental Protection, 2020).

In the Middle East, wells and water harvesting mechanisms have been utilized for decades as water and water storage sources during drought months. However,

Israel has been leading the efforts on water reuse with a desalination plant that uses reverse osmosis technologies to treat seawater for personal use and treat brackish water for agricultural use. This has proven to be a sustainable mitigation tool to reduce water pumping from the Sea of Galilee (Fanack Water, 2021). With both Florida and Israel being champions in the desalination field, others should adopt the strategy. This will act as a long-term water mitigation strategy which could then limit over-pumping from oceans and seas.

In Jordan, greywater reuse is employed in villages for agricultural use; this is treating and recycling water from kitchens, showers, baths, and laundry. Recycling greywater is an essential method for areas that suffer from water stress and excessive water needs for agricultural purposes. In addition, the recycling of greywater could result in a shift of community potable water use and conservation since they would use a local and sustainable water source for agriculture and other non-household needs instead (Al-Mashaqbeh, et al., 2012). Greywater in Jordanian villages is treated in the most cost and energy-efficient ways, activated sludge systems that involve aeration and sedimentation tanks, and sand and gravel filters which are low tech and low maintenance filtration systems. Sand and gravel filters work to remove physical threats for water being used for agricultural and non-household purposes only. The purpose of using sand and gravel is their biofilm properties which retain the toxic particles that allow for water to be treated (Huhn, et al., 2015).

Kassim Abdo mentioned the potential for water reuse projects in Palestine. However, there is significant reluctance towards such a thing due to the stigma behind using wastewater on olive trees which are the country's greatest asset. However, research conducted in the Gaza strip by multiple Palestinian agricultural organizations in the region over three years showed no significant difference between olive oil irrigated with treated wastewater and irrigated with fresh water. Stressing that when compared with international standards, the olive oil's quality parameters were of acceptable standards. Their research even highlighted the added nutrients found in the soil after treated wastewater was used (Barghouti, et al., 2017).

6.2 Kibbutzim in Florida

Olive harvest season in the Middle East is a family affair that encourages a bond between the members and avoids labor costs since olives are harvested by hand. Labor costs put landowners at a disadvantage since they may deter from the full profit potential. Palestinian families could be seen as informal cooperative-style communities, as they usually live in the same neighborhood and share the responsibility of caring for their family-owned olive groves. Additionally, olive growing communities in Palestine constitute a significant part of society, as olive trees are the country's most prosperous tree, and caring for the tree allows for a harvest that could serve the entire community. This cooperative style approach allows for high efficiency during olive harvest sessions. Cooperative style living or olive grove maintenance is beneficial since having a team of experts makes olive harvesting more efficient. Efficiency is essential when deciding to mill the olives since the longer they sit untouched, the more likely they are to bruise, affecting the quality of the olive oil (Qadus, 2019). Similarly, in Israel, the concept of the Kibbutzim, a co-op or collective living style that is traditionally agrarian, agricultural, and industrial-focused.

The recommendation here would be for local governments in Florida to adopt the concept. Co-op style living could then be a proposal for increasing job opportunities in the state and creating a more stable environment for prosperous olive oil production for commercial use. In addition, agricultural communities that have been affected by citrus greening could be encouraged to make the switch to olive grove cultivation. This state-funded program could result in a long-term benefit and the ultimate switch from citrus groves to olive groves in Florida. Additionally, during a phone conversation with Michael Garcia, he recommended that local prisons allow inmates to participate in concepts similar to the kibbutzim; they could be paid for their labor, creating a sense of financial stability for them when they finish their sentence (Garcia, 2021).

7. Conclusion

Olive trees have proven to be one of the most resilient trees; with sustainable practices, these trees could result in a successful cash crop that could benefit Floridian farmers who have been affected by citrus greening. Research on olive trees is happening every day in Florida as farmers and agricultural specialists look into the possibility of switching the state's production completely to olives. However, research that compiles expertise from the Middle East and that happening in Florida is not accessible.

As Florida moves to find its new state crop, this research paper can offer cumulative information on the history of olive groves and the cultivation requirements of olive trees in both Florida and the Middle East. Irrigation best practices have been explained in detail to benefit interested farmers. This study compiled best practice techniques and recommendations for changes in the olive cultivation industry for Floridian and Middle Eastern farmers.

The literature review suggests that olive grove cultivation could solely rely on water requirments and climate; however, additional themes were mentioned when the interviews were conducted. A significant challenge Floridian farmers expressed was maintenance techniques; this included irrigation, pruning, and fertilizers; tools Middle Eastern farmers had readily available to share. Those who incorporated their expertise into this research paper have given a worldly perspective to those interested in the olive grove industry. Olive trees must be nurtured and cared for as soon as their roots hit the ground. Therefore, all aspects of maintenance are critical, and constant observations for pests are crucial to ensure that the location of the olive tree is sustainable for long-term cultivation.

All in all, once proper attention is placed on siting, species, cultivation and irrigation olive groves could proposer successfully. Florida has the history and expertise of commercial citrus groves; this knowledge could be transferable when deciding to shift to olive groves. Local governments could spearhead these attempts and support local farmers in their strive to continue their production efforts.

8. References

Abdo, Kassim. (2021). Personal Interview, Freelance agriculture, climate change, water, and environment consultant.

AlKhader, Asad. (2021). Personal Interview, Soils and irrigation Specialist.

Alhairy, Masnat. (2018). Competitiveness of Olive Crop in Jordan. Retrieved from https://egyptssp.ifpri.info/2018/04/15/competitiveness-of-olive-crop-in-jordan/

Al-Jaloudy, Mahmoud. (2015). Jordan. Retrieved from https://www.yieldgap.org/jordan

Al-Mashaqbeh, O., Ghrair, A., Megdal, A. (2012). Grey Water Reuse for Agricultural Purposes in the Jordan Valley. Retrieved from file:///Users/renaduri/Downloads/water-04-00580.pdf

AQUASTAT Global Water Information System. (2019). Jordan. Retrieved from https://storage.googleapis.com/fao-aquastat.appspot.com/countries_regions/factsheets/water_resources/en/JOR-WRS.pdf

Barghouti, Z., Alimari, A., Qurie, M., Amereih, S., Al-Dadah, J. (2017). Using Non-Conventional Water in Irrigation of Olive Trees and Its Effect on Olive Oil Properties. Retrieved from https://m.scirp.org/papers/80527

Byron, M., Phillips, E., Gillett-Kaufman, J. (2019). Develop your own Florida olive IPM plan. Retrieved from https://edis.ifas.ufl.edu/pdf/IN/IN125100.pdf

Caballero, G. (2021). Is Roundup too dangerous for personal lawn care use?. Retrieved from https://www.yourgreenpal.com/blog/is-roundup-too-dangerous-for-personal-lawn-care-use

Chaney, C. (2021). Olives and Cross-Pollination. Retrieved from https://homeguides.sfgate.com/olives-crosspollination-70521.html

Carr, M. (2013). The water relations and irrigation requirements of olive. Retrieved From https://www.researchgate.net/publication/259436318_The_water_relations_and_irrigation_requirements_of_olive_Olea_europaea_L_A_review

Cook, B. (2018). Producing Tradition: International Standards and Development in Jordanian Olive Oil. Retrieved from https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1066&context=geography_etds

Dag, A., Naor, A., Ben-Gal, A., Guy, H., Zipori, I., Schneider, D., Birger, R., Peres, M., Gal, Y., Kerem, Z. (2014). The Effect of Water Stress on Super-High-Density 'Koroneiki' olive oil quality. Retrieved from https://pubmed.ncbi.nlm.nih.gov/25214192/

Dede, Rizzo. (2021). Personal Interview, The Olive Grove owner.

Dettenmayer, Lynn. (2021). Personal Interview, Jefferson Olive Groves owner.

Dobson, M. (1995). Tree Root Systems. Retrieved from https://www.trees.org.uk/Trees.org.uk/files/61/6181f2b7-e35d-4075-832f-5e230d16aa9e.pdf

EcoPeace. (2020). Sustainability. https://old.ecopeaceme.org/projects/sustainabilitiy/

Fanack Water. (2015). Climate and Rainfall in Palestine. Retrieved from https://water.fanack.com/palestine/climate-and-rainfall/

Fanack Water. (2021). Water Resources. Retrieved from https://water.fanack.com/israel/water-resources/

Fereres, E., Villalobos, F.J., Orgaz, F., Testi, L. (2011). Water requirements and irrigation scheduling in olive. Retrieved from https://www.ishs.org/ishs-article/888_2

Florida Citrus. (2018). A History of Citrus Greening. Retrieved from

https://www.floridacitrus.org/newsroom/citrus-411/citrus-greening/a-history-of-citrus-greening/

Florida Climate Center. (2021). Agricultural Forecasting. Retrieved from https://climatecenter.fsu.edu/topics/agricultural-forecasting

Florida Department of Agriculture and Consumer Services. (2021). Agricultural Best Practices. Retrieved from https://www.fdacs.gov/Agriculture-Industry/Water/Agricultural-Best-Management-Practices

Florida Department of Environmental Protection. (2020). Alternative Water Supply. Retrieved from https://floridadep.gov/water-policy/water-policy/content/alternative-water-supply

Florida Department of State. (2021). State Soil. Retrieved from https://dos.myflorida.com/florida-facts/florida-state-symbols/state-soil/

Fereres, E., Soriano, Maria. (2006). Deficit irrigation for reducing agricultural water use.

Retrieved from https://academic.oup.com/jxb/article/58/2/147/534071

Fereres, E., Moriana, Al., Orgaz, F., Pastor, M. (2003). Yield Responses of a Mature Olive Orchard to Water Deficits. Retrieved from https://www.researchgate.net/publication/279903757_Yield_Responses_of_a_Mature_Olive_Orchard_to_Water_Deficits

Florida Olive Council. (2020). Don Mueller. Retrieved from https://floridaolive.org/team/don-mueller/

Florida Olive Council (2020). Search for a “low chill” olive variety. Retrieved from https://floridaolive.org/

Florida Olive Council. (2020). The Importance of Irrigating Olives. Retrieved from

https://floridaolive.org/olive-irrigation/

Florida Olive Council. (2020). The Olive. Retrieved from https://floridaolive.org/

Florida Olive Council. (2021). Michael Garcia. Retrieved from https://floridaolive.org/team/michael-ohara-garcia/

Florida Organic Growers. (2020). Building a Sustainable Future. Retrieved from https://foginfo.org

Garcia, Michael. (2020). Establishing an Olive Industry in Florida. Retrieved from https://vscnews.com/establishing-an-olive-industry-in-florida/

Garcia, Michael. (2018). Low-Chill Florida Olive. Retrieved from file:///Users/renaduri/Downloads/LowChillOliveUpdate-Dec2018copy.pdf

Garcia, Michael. (2021). Personal Interview, President of the Olive Council.

Ghose, Tia. (2013). The Origins of the Olive Tree Revealed. Retrieved from https://www.scientificamerican.com/article/the-origins-of-the-olive/

Gillett-Kaufman, J., Allan, S., Bosques-Mendez, J., Buss, L. (2014). Pests and Fungal Organisms Identified on Olives in Florida. Retrieved from https://edis.ifas.ufl.edu/publication/IN1046

Higgins, A. (2019). Whether or not Roundup is safe, the gardener has better options. Retrieved from https://www.washingtonpost.com/lifestyle/home/whether-or-not-roundup-is-safe-the-gardener-has-better-options/2019/09/17/8ccb8a5e-ca95-11e9-a1fe-ca46e8d573c0_story.html

Horticulture Innovation Australia. (2020). Olive best practice manual. Retrieved from https://olivebiz.com.au/wp-content/uploads/2020/08/Manual-revised.pdf

Huhn, L., Deegener, S., Gamisonia, R., Wendland, C. (2015). Greywater treatment

in sand and gravel filters. Retrieved from http://www.wecf.org/wp-content/uploads/2018/11/Manualgreywaterfilter_website.pdf

Ibrahim, Noor. (2019). Olive groves in the West Bank have become a battleground. Retrieved from https://time.com/5714146/olive-harvest-west-bank/

IFAS. (2016). Olives. Retrieved from https://gardeningsolutions.ifas.ufl.edu/plants/edibles/fruits/olives.html

Jefferson Olive Groves. (2021). The Olive Trees. Retrieved from https://jeffersonolivegroves.com/

Kadyampakeni, D., Morgan, K., Zekri, M., Ferrarezi, R., Schumann, A., Obreza, T. (2017). Citrus irrigation management. Retrieved from https://edis.ifas.ufl.edu/pdf/SS/SS66000.pdf

Khalidi, Ahmad. (2013). Image title [Jordan and its neighbors]. Retrieved from https://www.opendemocracy.net/en/palestine-peoples-and-borders-in-new-middle-east-map/

Lavee, S., Hanoch., E., Wodner, M., Abramovich, H. (2007). The effect of predetermined deficit irrigation on the performance of cv. Muhasan olives (Olea europaea L.) in the eastern coastal plain of Israel. Sci. Hortic. 112: 156-163.

Lavee, S., Nashef, M., Wodner, M., & Harshemesh, H. (1990). The effect of complementary .”

irrigation added to old olive trees (Olea europaea L.) cv. Souri on fruit characteristics, yield, and oil production. *Advances in Horticultural Science, 4*(3), 135-138. Retrieved April 24, 2021, from http://www.jstor.org/stable/42881554

Loumou, Angeliki. (2003). Olive Groves: “The life and identity of the Mediterranean.”

Retrieved from https://link.springer.com/article/10.1023/A:1022444005336

Massad, R. (2021) Personal Interview, Agricultural Activist.

Majdalani, N. (2021). Personal Interview, The Palestinian Director of EcoPeace.

Mcpherson, H. (2016). Richard Williams, Florida Olive Systems. Retrieved from https://www.orlandosentinel.com/food-restaurants/os-richard-williams-culinary-hall-of-fame-20160229-story.html

Ministry of Foreign Affairs of the Netherlands. (2018). Climate Change Profile: Jordan. Retrieved from file:///Users/renaduri/Downloads/Jordan.pdf

Mission Resource. (2021). Nutrient Best Management Practices. Retrieved from https://www.missionrcd.org/nutrient-best-management-practices

Naoum, S., Ayoub, S., Albalawneh, A., Diab, M. (2018). Productivity of water, growth, and yield of olive trees under deficit irrigation. Retrieved from https://www.researchgate.net/publication/325124546_Productivity_of_water_growth_and_yield_of_olive_trees_under_deficit_irrigation

Nelson, Diane. (2019). 75 percent of Florida's oranges have been lost to the disease. Can science save citrus?. Retrieved from https://www.universityofcalifornia.edu/news/75-percent-floridas-oranges-have-been-lost-disease-can-science-save-citrus

Olive Oil Source. (2021). Site Selection. Retrieved from https://www.oliveoilsource.com/page/site-selection

O'Malley, M. (2001). Soil Sterilization. Retrieved from https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/soil-sterilization

OXFAM. (2010). The road to olive farming: challenges to developing the economy of

olive oil in the West Bank. Retrieved from https://oxfamilibrary.openrepository.com/bitstream/handle/10546/115032/bp-road-to-olive-farming-west-bank-151010-en.pdf

Patton, G. (2019). Organic does not mean pesticide-free. Retrieved from https://www.johnson.k-state.edu/lawn-garden/agent-articles/environment/organic-does-not-mean-pesticide-free.html

Qadous, Naser. The importance of cooperatives in Palestine. Retrieved from https://www.anera.org/blog/the-importance-of-cooperatives-in-palestine/

Rivulis. (2019). Using Micro Irrigation to Support Innovative Intensive Olive Farming. Retrieved from https://www.rivulis.com/project/olives-israel/

Samish, R.M. and Spiegel, P (1961). The use of irrigation in growing olives for oil production. Israel Journal of Agric Research. 11:87-95.

Soil Science Society of America. (2013). Myakka Florida State Soil. Retrieved from https://www.soils4teachers.org/files/s4t/k12outreach/fl-state-soil-booklet.pdf

Sultan, S., Abu-Sharekh, M., Nazer, S. (1995). Image title [Types of Cisterns in the West Bank]. A printed report titled “Rainwater Roof Catchment Systems from Household Water Supply".

Testi, L., Orgaz, FVillalobos, F., Fereres, E. (2005). Water Requirements of olive orchards - II: determination of crop coefficients for irrigation scheduling. Retrieved from https://link.springer.com/article/10.1007/s00271-005-0012-x

Teviotdale, L., Sibbet, G. (1995). Consistent annual treatment helps future olive leaf spot control. Retrieved from https://pdfs.semanticscholar.org/9bd2/e1b3033eade62af97415db6be2399a80ae82.pdf

The Olive Grove. (2021). About us. Retrieved from http://floridaconcerts.org/

Thetford, M., Gillett,Kaufman, J., Mulvaney, M. (2018). Olives for Your Florida Landscape. Retrieved from https://edis.ifas.ufl.edu/ep515

The Jordan Times. (2018). Olive trees cover 72% of Jordan's agricultural land. Retrieved from https://jordantimes.com/news/local/olive-trees-cover-72-jordans-agricultural-land

The Science Times. (2019). The Life Cycle of an Olive. Retrieved from https://www.sciencetimes.com/articles/18187/20190213/life-cycle-olive.htm

Theorner, Jutta. (2020). We love "Olive." Retrieved from https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=44360

UF/IFAS. (2020). UF Institute of Food and Agricultural Sciences. Retrieved from https://ifas.ufl.edu

United States Environmental Protection Agency (EPA). (2020). Micro Irrigation. Retrieved from https://www.epa.gov/watersense/microirrigation

United States Environmental Protection Agency (EPA). (2013). Saving Water in Florida. Retrieved from https://www.epa.gov/sites/production/files/2017-02/documents/ws-ourwater-florida-state-fact-sheet.pdf

USAID. (2016). Jordan's households save water and traditions. Retrieved from https://2012-2017.usaid.gov/results-data/success-stories/saving-water-and-family-traditions

Vossen, Paul. (2007). Olive Oil: History, Production, and Characteristics of the

Worlds Classic oils. Retrieved from https://www.researchgate.net/publication/242322964_Olive_Oil_History_Production_and_Characteristics_of_the_World's_Classic_Oils

Wafa. (2021). Olive Tree Varieties (in Arabic). Retrieved from https://info.wafa.ps/ar_page.aspx?id=8435

Welkerson, Jordan. (2015). Roundup Ready Crops Have Lost their Allure. Retrieved from https://sitn.hms.harvard.edu/flash/2015/roundup-ready-crops/

Wild Florida EcoTravel Guide. Image Title [Florida Regions Map]. Retrieved from http://www.wildflorida.com/florida_map.php

Zhang, M., Young, G., Migliaccio, K., Fraisse, C. (2017). Florida rainfall data, On the other hand, when sources and types. Retrieved from https://edis.ifas.ufl.edu/publication/AE517

Appendix 1

Semi-structured interview questions to be asked to experts in the field of olive cultivation:

- When planting a new olive tree, what do you do?
    - What is the prepping process?
    - How do you know where to place it?
    - Is there a specific type of tree that works in Palestine over others that do not? What are they called?
- Do you use fertilizer? What kind? How often? Maybe potassium?
- Do you spray your crops for pests and diseases? If yes, what kind and how often?
    - What type of pests have you seen on olive trees specifically?
    - What is the treatment?
- Where does the water you use to water your crops come from? How do you ensure it has not been contaminated?
- Did you install the irrigation?
    - What type of irrigation is it? How does it work?
    - What do you do during dry months? How often do you water your crops?
- How do you care for an olive tree long-term?
- Do you think olive trees can grow anywhere? Why or why not?
- What advice do you have to give to farmers or agricultural experts in Florida for their new olive grove production plan?
- What does sustainability mean to you? Moreover, how do you implement it in the field?
- What does unsustainable olive oil production look like to you? Furthermore, what does sustainable olive oil production look like?