Natural Resources and Sustainable Development **Volume 13, Issue 2, 2023 DOI: 10.31924/nrsd.v13i2.137**

KEY FACTORS INFLUENCING OLIVE YIELDS FOR SUSTAINABLE DEVELOPMENT IN ARID REGIONS OF DJELFA AND M'SILA, ALGERIA

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Abstract

In Algeria, there is an increasing extension of olive grove cultivation, it is essential to identify the key factors that contribute that drive olive grove yields in drought-prone regions, such as steppe. This necessity is becoming imperative for policymakers within the agricultural sector, as it will enable them to make informed decisions regarding more effective strategies for expanding olive tree plantations across the country.

This paper focuses on analysing the olive tree production systems in two provinces in the Algerian steppes: Djelfa and M'sila. These provinces represent new areas for olive cultivation and demonstrate successful agricultural programs in Algeria.

The paper proceeds to address the question: what are the primary factors influencing olive grove yields? This inquiry is pursued by investigating a total of 20 olive growers, ten from each province. The findings from our research indicate that olive groves situated at higher altitudes (above 600 meters above sea level), on gently sloping terrain (ranging from 0 to 0.03), and managed through the application of technical itineraries and effective management practices by well-educated and younger farmers, tend to yield better results in terms of olive production. Furthermore, the impact of governmental subsidies and policies related to land tenure regularization also exerts a significant effect on enhancing production and yielding improved outcomes.

Key words: steppe, olive-trees, yield, altitude, slope, factors

INTRODUCTION

The olive tree, *Olea europea L.*, was perceived for a considerable period as a rustic tree that bore fruit without human intervention (Abdul Hussain and Abdul Hussain, 2004; Istanbouli, 1976; Mazliak et al., 1982). It is a long-living plant, with a lifespan of at least several hundred years, as documented by Loussert and Brousse, 1978. The fruit is one of the oldest agricultural tree crops, and the plant produces oil. Its cultivation most likely began in the third millennium B.C. in the eastern Mediterranean holding an importance as a prominent agro-ecosystem in the Basin with enormous socioeconomic relevance (Loumou et al., 2003).

Although olive production plays a role in the economies of Mediterranean countries (Gregoriou et al., 2007), and may be regarded as a strategic crop in the area because it is extremely resistant to dry periods, drought, and able to obtain an adequate yield under dry farming (de Graaff et al., 2010; Duarte et al., 2008; Freixa et al., 2010; Tanasijevic et al., 2014).

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Historically, olive culture has played a significant role in rural development and poverty alleviation across the Middle East and North Africa (Lybbert and Elabed, 2013).

Algeria is one of the Mediterranean countries that produces olive oil, and olive growing dates back several centuries. Olive-growing is an important activity for families.

It is a subsistence culture that is concentrated in mountainous areas in the central and eastern parts of the country. It is an important element in national agricultural development, accounting for 4 % of the agricultural land area and 40% of the total orchard area (MADR, 2021).

The olive sector in Algeria can play a key role as a driver of development and rural empowerment, diversifying the country's economy through non-hydrocarbon exports (Hachemi et al., 2023). Olive growing is considered one of the strategic sectors and receives special attention from the government through various development programs and supportive measures. This has revitalized the olive industry by expanding olive cultivation to other areas, which have subsequently become significant olive-growing hubs, notably Djelfa and M'sila, the primary focus of our study.

Olive cultivation in Algeria has shown a remarkable rate of expansion, driven mainly by economic, social, and cultural reasons. In 1999, olive cultivation was concentrated in only 11 provinces. However, substantial progress has been made through the strategic implementation of Algerian agricultural development policies. This development is reflected in the significant expansion of olive tree cultivation in most provinces, including the geographical area of our study (Fig. 1).

In Algeria, the olive tree occupies a huge expanse of 431,508 hectares. Within this context, our allocated study region contributes significantly, representing 5.05% of the nation's total olive growing area. Moreover, our study area commands 8.61% of the overall number of planted olive trees, completing an astounding count of 60,632,901 trees.

The olive tree has a biannual productivity cycle (Rojo et al., 2015). This well-known pattern aligns with the olive tree's physiological balance, which takes two years to complete the whole biological life cycle (Rallo et al., 1991). Conversely, environmental conditions intensify this interannual alternation in fruit output, which is a key source of worry for olive growers and the olive oil sector due to its potential impact on productivity (Orlandi et al., 2017).

The fluctuations in olive yield and production observed within the steppic zones of Djelfa and M'sila, constitute a significant concern. In order to understand the underlying drivers of this phenomenon, a comprehensive survey was conducted, involving a cohort of 20 olive growers, including ten farmers hailing from each respective province (Djelfa and M'sila). Additionally, this study aims to discover the primary parameters impacting olive fruit yield in this region. This will be achieved through the characterization of olive tree environmental requirements and human-based factors in the Steppe region. Followed by an analysis of their impacts on olive yields.

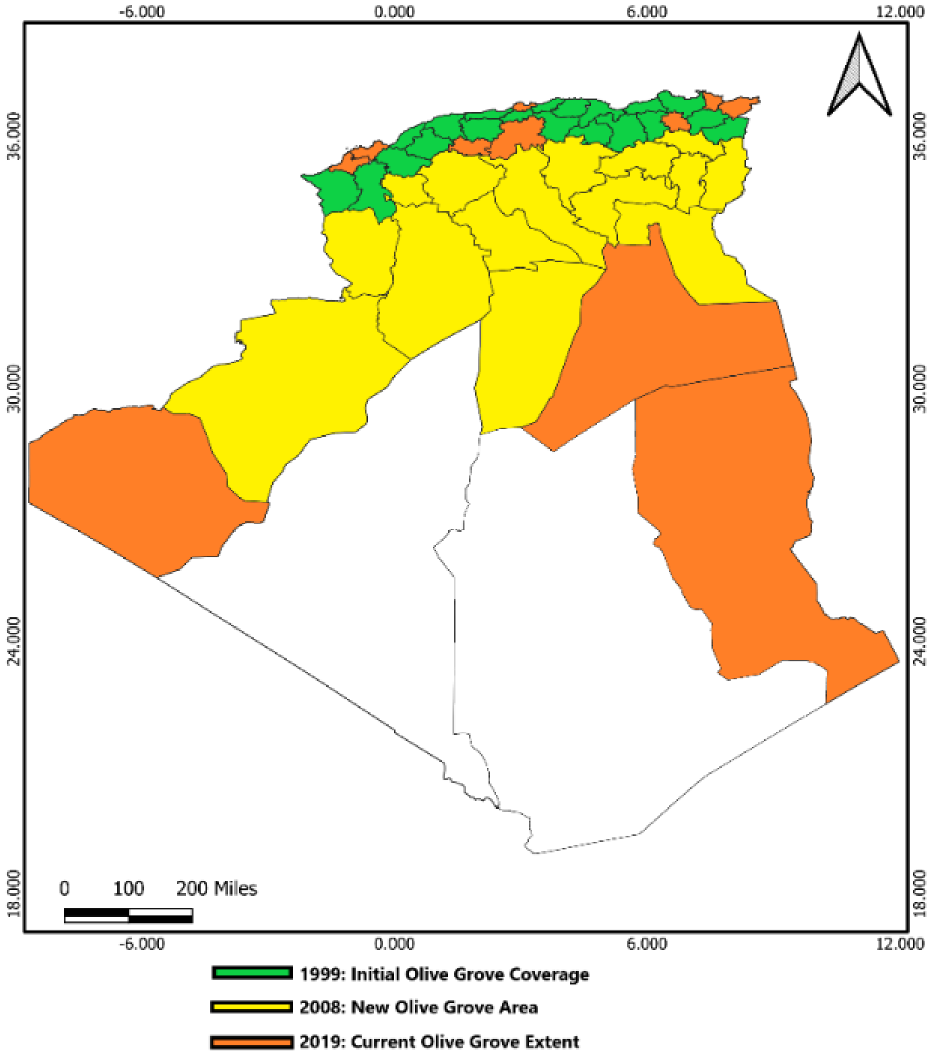

Fig. 1. Expansion of Olive Cultivation in Algeria from 1999 to 2019

MATERIAL AND METHOD

Study area

Due to the significance of steppe regions and their emergence as new olive-growing areas in Algeria, we have focused our study on the Djelfa and M'sila provinces.

The province of Djelfa is situated in the central part of Algeria, extending beyond the southern boundary of the Tellian Atlas. It ranges between 34° 480 and 35° 320 North latitude and 2° 280 and 4° 190 East longitude, approximately 300 km south of Algiers, and covers a total area of 32,362 km^2, which is approximately 1.36 % of the country's total land area. Apart from its vast territory, Djelfa holds a strategic position at the center of the Great Plateaus (Cherfaoui, 2017). In similar vein, the province of M’Sila is positioned in central-eastern Algeria; it is located between 35° 180 and 35° 320 North latitude and 4° 150 and 5° 060 East longitude, lying approximately 300 km south of Algiers (Benikhlef et al., 2021). The location of the study area is shown in Figure 2.

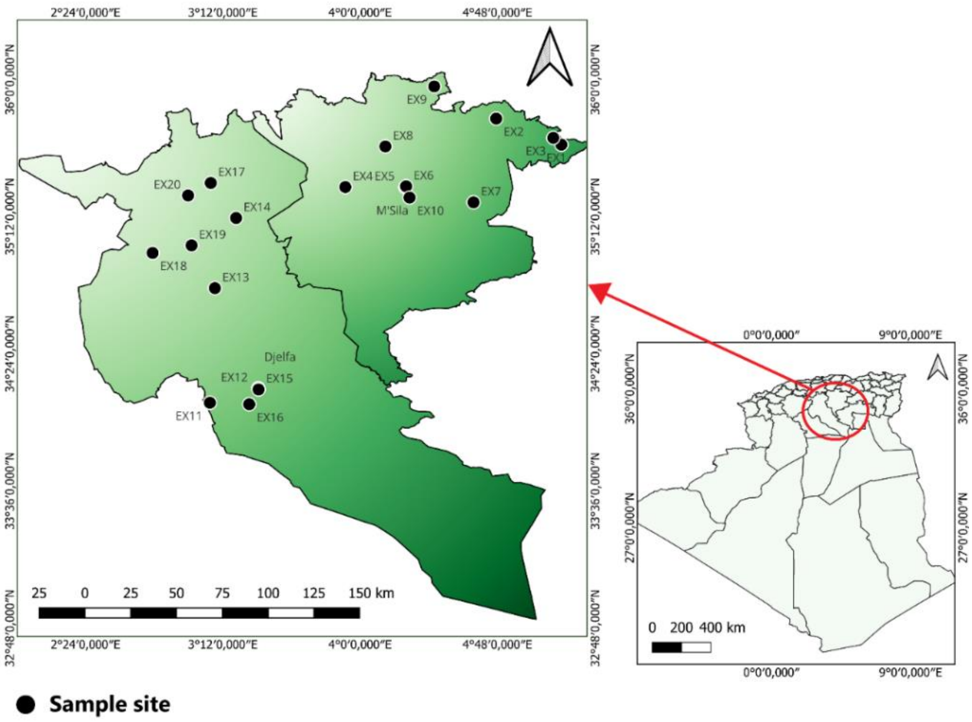

Fig. 2. The study area

According to Harkat et al., 2023, using climate data obtained from Algeria's National Office of Meteorology for the years 1999 to 2009 for the two provinces of Djelfa and M'Sila. The results of the Q3 pluviothermic coefficient of Emberger-Sauvage (Sauvage, 1963) modified by Stewart, 1975, towards both provinces experiencing an arid climate stage (Table 1).

Additionally, these two regions are notably distinguished by their vast expanses of steppe ecosystems, which cover impressive areas of their territories.

Table 1

Climate Data for Djelfa and M'sila Regions (time period of data between 1999 and 2009) The values of means and standard errors are provided

	Rainfall mm	m, °C	M, °C	Q3
Djelfa	284.0 ± 21.0	-0.35 ± 0.48	34.6 ± 0.33	27.90
M'sila	192.85± 22.4	3.19 ± 0.49	39.4 ± 0.33	18.27

(Source: Harkat et al., 2023)

Data Collection

The study's sources for data on the surfaces, yield, and production of the olive grove from 2012 to 2021 were the directions of agricultural services in M'sila and Djelfa.

To explore the main factors on a small scale, a survey was carried out among 20 olive growers from the major olive-growing provinces of the Steppe area, particularly the provinces of Djelfa and M'sila. The questionnaire has been designed to provide data and measure a number of variables. Data were collected through a survey that included different interviews with 20 farmers (Table 2). They were selected randomly for these interviews, which took place from January 2023 to June 2023.

Furthermore, to avoid the impact of alternate bearing, we also calculated the two-year average of production and yield values for each olive grove farm.

The questionnaire contains questions regarding the olive grower's profile, including their level of education and agricultural training. It also examines aspects of their agricultural operation, such as land ownership status and government support. Furthermore, it delves into agricultural practices by examining factors such as planting density, cultivated area, production indicators, yields, and the observation of diseases and pests. Moreover, the use of fertilizers and pruning practices are also examined.

In addition to the aforementioned factors, our study also considered environmental variables, specifically altitude and slope, as crucial determinants of the study area's characteristics. To evaluate their impact, we used digital elevation data gathered from Google Earth, providing a comprehensive assessment and analysis of the terrain's influence on the study area.

Data Analysis

The data obtained were subjected to statistical analysis, encompassing Pearson's correlation and principal component analysis. These analytical procedures were executed employing the PAST version 04 and ExcelSTAT version 15 software tools.

Table 2

Key Olive Grove Characteristics

Point	Latitude (N)	Longitude (E)	Area (ha)	Altitude (m)	Slope	Grove planting year
EX1	35.620000°	5.172861°	30	842	0.1	2008
EX2	35.772028°	4.793167°	45	816	0.014	2014
EX3	35.659722°	5.125722°	6	1045	0.018	2013
EX4	35.372778°	3.914167°	10	861	0	2006
EX5	35.372500°	4.263056°	45	816	0.014	2014
EX6	35.377307°	4.268120°	20	830	0.018	2014
EX7	35.283750°	4.661056°	120	873	0.023	2008
EX8	35.609722°	4.147500°	20	858	0.008	2013
EX9	35.959722°	4.431944°	30	853	0.01	2013
EX10	35.311389°	4.288333°	40	736	0.01	2005
EX11	34.114873°	3.125044°	3.5	602	0	2006
EX12	34.199444°	3.406733°	6	726	0.047	1995
EX13	34.783353°	3.154222°	4.5	649	0	1983
EX14	35.192399°	3.277797°	1	460	0.002	2007
EX15	34.192187°	3.408467°	3	425	0.013	2003
EX16	34.106137°	3.354179°	3	421	0.009	1998
EX17	35.396861°	3.129952°	21.75	431	0.014	1991
EX18	34.988755°	2.791211°	12	700	0	2011
EX19	35.032749°	3.018199°	3	909	0.036	1993
EX20	35.323833°	2.997857°	3	451	0.006	1998

RESULTS AND DISCUSSION

Comparative olive production dynamics in Djelfa and M’sila Provinces

The following Figure 3 shows that, over the past decade, the production of table olives in Djelfa province has experienced significant variations. It reached a peak in 2018 with 46.20 q/ha, but also had less fruitful years like 2013 and 2017, with 17.90 q/ha and 19.40 q/ha, respectively.

In contrast, the production of table olives in M'sila province has been generally more stable compared to Djelfa. It ranged between 14 q/ha in 2015 and 30 q/ha in 2012, with a slight downward trend after 2012 until 2014, followed by stabilization around 25 q/ha until 2022.

Regarding olive oil production, both provinces have recorded relatively constant values. In Djelfa, the olive oil production varies between 13 and 21

L/q, while in M'sila province, it oscillates between 9 and 28 L/q, with a general downward trend until 2015, followed by a slight increase.

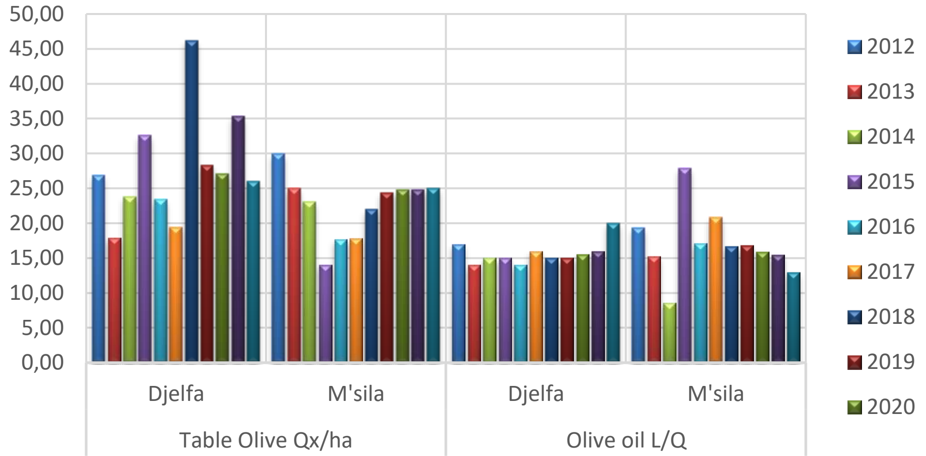

Fig. 3. Evolution of Olive Oil and Table Olive Production from 2012 to 2022 in the Djelfa and M'sila provinces

These fluctuations can be interpreted as a result of the alternate bearing phenomenon or other factors such as weather conditions, agricultural practices, diseases or pests affecting olive trees, and fluctuations in the olive oil yield.

This phenomenon is observed not only in our study area but also in various olive-growing regions around the world. In central Spain, the olive fruit yield of Olea europaea shows large annual fluctuations, with high production years tending to alternate with years of low productivity (García-Mozo et al., 2008).

Given the local reality and the characteristics of the production systems in the region, and in order to measure the impact of the selected factors on olive yields, our study aims to assess the influence of selected factors on olive yields through a statistical analysis that highlights their effects. It is important to note that, due to the complex nature of these factors, quantifying the precise degree of contribution for each variable remains challenging.

Results from the survey

Influence of climatic factors (Temperature and Rainfall)

Pearson's correlation coefficients were calculated for yields (table olives and olive oil) and climate variables, such as mean temperatures (°C) and annual rainfall (mm), for the period from 2012 to 2022 in the two provinces. According to Figure 4 below, we notice that there is a weak negative correlation between the average yield of olive oil, temperature, and precipitation in the M'sila province. The correlation coefficients obtained are (r = - 0.334, p = 0.128) and (r = - 0.283, p = 0.020), respectively.

Conversely, in Djelfa province, the same analysis reveals a strong positive correlation, especially between rainfall and table olive yield, with a coefficient (r = 0.725, p = 0.0001) and a moderate positive correlation with olive oil yield (r = 0.456, p = 0.032). Also, the temperature recorded a slight positive correlation with olive oil yields, with a coefficient of (r = 0.377, p = 0.083).

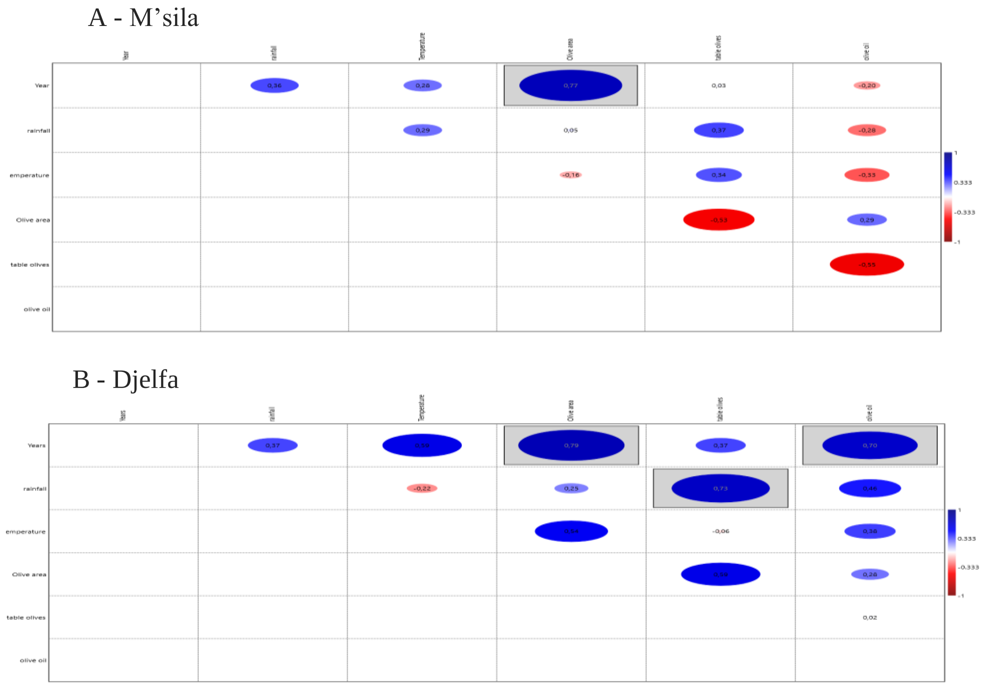

Fig. 4. Correlation matrix plot showing Pearson’s correlation coefficient between yields and climatic factors in the two provinces. Calculated using the Pearson’s coefficient ($p \leq 0.05$)

Djelfa has a slightly more Mediterranean-influenced climate with less drought susceptibility compared to the more desert-like, drought-prone climate in M'sila based on the climate indices analyzed. Their analysis of climate indices like SPI (standardized precipitation index), PDI (percent of normal precipitation index), and ratio to normal shows Djelfa has more favorable climate conditions compared to M'sila.

These more favorable climatic conditions in Djelfa are reflected in higher olive grove production. Survey data shows average olive yields in Djelfa reached 96.675 ± 0.758 q/ha, compared to 61.1 ± 0.676 q/ha in the surveyed olive groves in M’sila.

In fact, air temperatures and water availability greatly influence crop development, which eventually impacts crop yields (Vossen, 2007). Generally, the olive is a long-lived, drought-tolerant plant restricted by frost and high temperatures and, to a lesser degree, by soil water (Connor and Fereres, 2010).

As observed in comparable studies in other climate locations, the association between yield and weather-related variables becomes clear at the key time of flower growth and ripening. It has been established that rainfall during fruit ripening exerts a major influence on ultimate fruit production in locations with a dry climate.

According to Ponti et al., 2014, temperatures of < -8.3 °C harm olive and limit its northward distribution, but annual rainfall of < 350 mm y-1 limits its distribution in drier locations.

Human and socioeconomic factors

- ***Socio demographic profile***

The age distribution of olive grove farmers in the study area is provided in Table 3. Approximately 15 % of the farmers were of retirement age (above 71 years old), while 65 % fell within the age range of 51 and 70. Only four farmers (20 %) were younger than 50 years old. These data indicate that the average age of olive growers in M'sila is 61.4 ± 0.226 years, whereas in Djelfa province, it is notably younger at 55.6 ± 0.081 years.

Table 3

Sample's socio-demographic profile (N=20, frequency, percentage in brackets)

		GENDER	AGE (YEARS)			
OLIVE GROWERS	N (%)	Female	Male	≤ 50 Young Adults	51-60 Middle-Aged Adults	≥ 71 Elderly
	20	0	20	4	13	3
	100 %	0	100 %	20 %	65 %	15 %

It should be mentioned that all the olive growers involved in the study were male. There were no female farmers, which can be linked to the conservative cultural practices prevalent in the region.

- ***Educational level***

The findings of the survey reveal a varied variety of educational profiles among the olive farmers. Out of the olive producers, three had formal agricultural training, while the rest had no formal agricultural experience. By the same token, the educational breakdown among the farmers covered 5 % with elementary education, 60 % with secondary education, and 35 % with university degrees. This variation in educational degrees gives a good opportunity for knowledge sharing and the adoption of novel approaches to the goal of sustainable olive farming (Fig. 5).

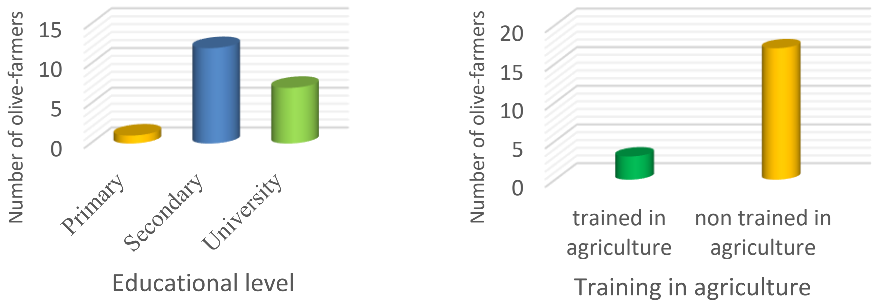

Fig. 5. Educational Level and Training in Agriculture of Sampled Olive growers

The younger organic farmers in Spanish olive orchards have less farming experience but more education and involvement in management, more positive attitudes about organics, and greater openness to change compared to older, conventional farmers with longer tenure in agriculture.

- ***Land tenure***

According to Figure 6, in terms of land tenure, 64 % of farmers profited from the 18-83's Law, which is an Algerian law governing access to agricultural land. While 22 % got land through concession agreements. Only 12 % own private properties, most of which are likely older. This demonstrates the region's reliance on Law 18-83, which has fostered faith and confidence among olive farmers that the land belongs to them. This heightened sense of ownership has significantly influenced productivity as farmers feel certain of their land rights and security.

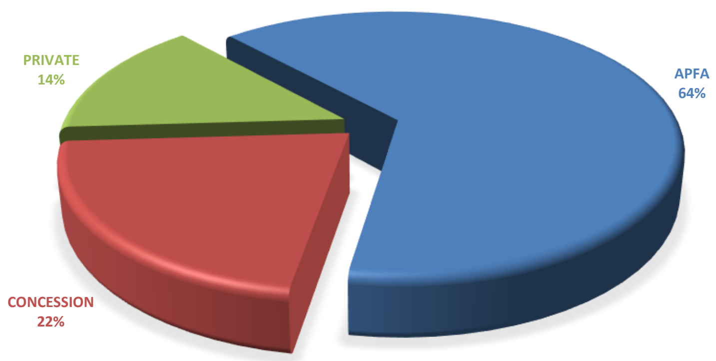

Fig. 6. Nature of land tenure and ownership in surveyed olive farms

It was shown that the APFA law catalyzed land privatization, irrigation infrastructure development, and incentives for high-value crops. This directly enabled the expansion and intensification of production on newly cultivated lands.

- ***Government Subsidies Status***

The distribution of olive groves based on their subsidy status from the government shows that 65 % of olives groves receive subsidies from the government, unlike the rest, which declare that they don't have access to governmental support. Such results indicate that the government recognizes the importance of supporting olive cultivation in semi-arid regions. On the other hand, the non-subsidized olive groves are all from M'sila province.

The main subsidies (irrigation infrastructure, trees, and other inputs) play a crucial role in intensifying crop diversification and agricultural development, especially since the 2000s under the PNDA subsidy program (Hamamouche et al., 2018), which was considered a major factor in the expansion of olive cultivation in steppe and arid areas of the country due to agricultural policies and programs.

Effect of Environmental Factors on Yields

- ***Altitude***

The agro-ecological stage at which the plants are grown is crucial to their adaptations and affects their production levels. As such, altitude is an important factor in measuring the appropriate range for good ecological adaptation of the variety.

We notice from the data (Table 4) that 30 % of the surveyed farms are located at altitudes below 600 meters, while the others (70 %) are located at altitudes above 600 meters. However, the altitude level of 600 meters is taken as a reference since it is considered a critical point for the adaptation of the Chemlal variety.

Table 4

Distribution of olive farms, yield, and oil productivity by the altitude

	number of olive farms	Percentage (%)	Yield	
			q/ha	L/q
under 600	5	25 %	65.2	18
up 600	15	85 %	83.45	15.2
Overall	20	100 %	78.89	15.9

The analysis of the effect of altitude gives us two groups: the first consists of farms located in an altitude range below 600 meters with an average yield of olive oil of 18 L/q higher than the average; conversely, the second group consists of farms located at an altitude above 600 meters, displaying an even higher than average yield of 78.89 L/q.

This table emphasizes the favorable effect of altitude on agricultural output within the stated range of altitudes. However, the low fluctuation in yield seen over a wide range of altitudes suggests that the culture studied is resistant to altitude changes of up to 800 meters, which is in good agreement with the other studies that have shown that the olives also grow at various altitudes, from sea level up to 900–1000 m a.s.l. (even at 1200 m a.s.l.) (Arenas-Castro et al., 2020).

Also, the scenario proposed by Tanasijevic et al., 2014, expects that the suitable locations will shift to the north, towards the inland, and to a greater altitude than at present.

- ***Slope exposure***

The various terrains of the region as well as the agro-ecological needs of planted olive trees lead us to classify the farms in respect to the slope and their influence on yields.

Areas with a flat slope demonstrate the best compromise, showcasing both a high yield in q/ha and a moderate yield in L/q. It represents 65 % of the olive groves; the other classes are 15 % and 20 % for flat and steep slopes, respectively. Meanwhile, truly flat or excessively steep areas perform less effectively, either in one aspect or the other (Table 5).

Table 5

Distribution of olive farms, yield, and oil productivity by slope exposure

	Number of farms (%)	Yield q/ha	Yield L/q
Flat (0)	03 (15 %)	58	17
Gentle slope (0 - 0,03)	13 (65 %)	86	16
Steep slope (≥ 0,03)	04 (20 %)	77	16

This suggests that the slope of the terrain affects agricultural production, but a higher slope does not necessarily lead to a significant rise in yields beyond a certain threshold.

The data in the Table 6 relating to the application of Pearson's correlation coefficient shows a negative correlation between altitude and yield of olive oil (L/q), (r = - 0.573, p = 0.0001), while slope has no significant correlation with yields.

Table 6

Correlation's matrix of key environmental variables and olive yields

Variables	Yield q/ha	Yield L/ha	Altitude m	Slope %
Yield q/ha	**1**			
Yield L/ha	0.2529	**1**		
Altitude m	0.1729	-0.5738	**1**	
Slope %	0.2770	-0.0961	0.3004	**1**

Calculated using Pearson's correlation coefficient ($p \leq 0.05$)

The slope of the land is identified as a significant natural factor influencing olive production. The slope of orchards should be adequate for irrigation.

Contribution of Agronomic Factors to Yields

- ***Seize of farms***

The farms in our study were categorized based on land area into three groups:

Farms with a land area between 0 and 10 hectares (40 % of the sample) were small-scale olive farms. Despite their limited production capacity, they contributed to local olive production with an average yield of 43.62 q/ha and 15.375 L/q.

Farms with a land area between 10 and 30 hectares (40 % of the sample) were medium-sized olive farms. They achieved an average yield of 89.84 q/ha and 16 L/q.

Farms with a land area above 30 hectares (20 % of the sample) consisted of large-scale olive farms. This intensive system recorded the highest yields, averaging 127.5 q/ha and 16 L/q.

In the Spanish province of Jaén the larger farms exhibit different production advantages despite their inherent difficulties. Economies of scale—which emerge from the more effective use of resources—play an important part in increasing manufacturing output. The presence of this impact is most notable on smaller farms (around 5 hectares).

- ***Age of trees***

The data reveal that age has a major impact on yields. Thus, the group of farms with aged olive groves with an age above 30 years (35 % of the sample study) has a higher average yield, i.e., 23 L/q; while the lower average yield (13.9 L/q) is recorded in the young age class with an age below 15 years. As well as our results, some studies mentioned that the claim that well-maintained olive trees experience yield reduction with age is erroneous.

- ***Variety selection***

According to Figure 7 below, we notice that most olive production is provided by the Chemlal variety, which covers more than 80 % of the cultivars in the study area. However, 20 % of farms merge the Chemlal variety with other varieties, notably the Sigoise, Sévillana, or Arbequina.

80 percent of the olive growers use only the Chemlal variety in their olive cultivation. That can indicate that Chemlal variety is prevalent and popular among farmers because of its agronomic characteristics, its yield, or the quality of the oil produced. The variety of Chemlal, considered a hardy and late variety originating from Kabylia, occupies 40 % of the Algerian olive orchard, with high productivity intended for the production of oil, with a productivity of 14 to 18 L/q.

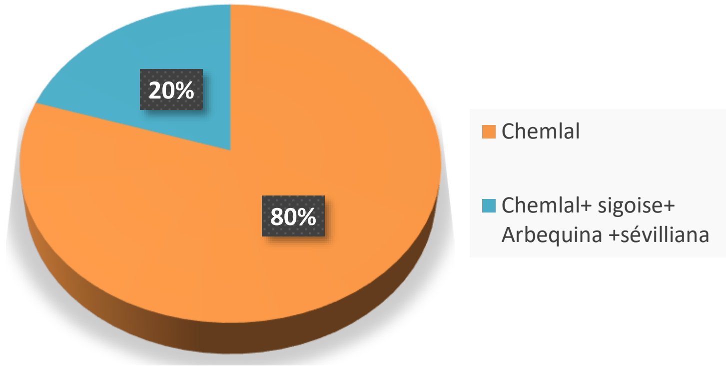

Fig. 7. Distribution of olive tree varieties in the sampled groves

- ***Intercropping***

According to our findings, the olive tree records an average yield of 83 q/ha and 16 L/q when cultivated in isolation. However, when intercropped with field crops, the average yield decreases to 78 q/ha, accompanied by a decline in the yield in L/q to 15. These results show a negative influence of field crop associations on both the quantity and quality of olive tree yields.

Conversely, when the olive tree is intercropped with market gardening, the average yield in q/ha reduces to 70, while the yield in L/q increases to 22. This association indicates a potential compromise between a decrease in quantitative olive oil production and an improvement in the oil's quality.

Moreover, when combined with arboriculture, the average yield in q/ha remains comparable to that of the olive tree alone, at 75.8. Similarly, the yield in L/q shows little variation, preserving a value of 16. These findings propose that the association with arboriculture has minimal influence on both the quantity and quality of olive tree production (Fig. 8).

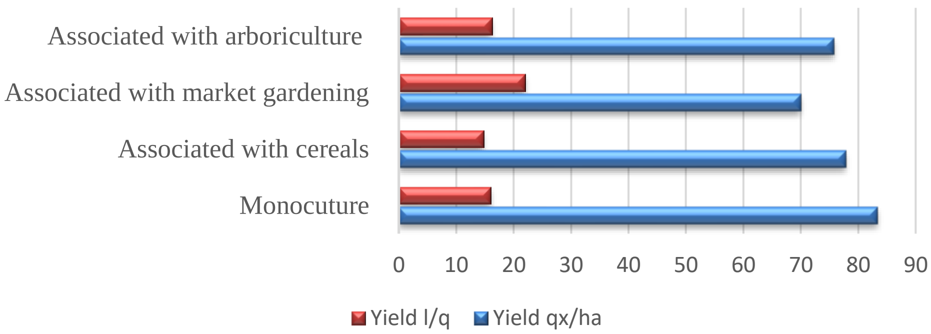

Fig. 8. Olive grove yields by cropping system

Competition for light, water, and nutrients between the olive trees and understory crops can reduce the yields of the intercropped species compared to monocultures.

In conclusion, our results reveal the variable effects of intercropping on olive tree yields. It is essential for farmers to prudently consider the choice of intercrop when defining optimal cultivation strategies for olive groves.

- ***Agricultural operations***

The data obtained from the variable fertilizer methods show that the farms that use organic methods (35 % of farms) record a moderate yield of 14.7 L/q, while farms that use chemical fertilizers (55 % of farms, especially in Djelfa) note the highest yield of 16.9 L/q.

Except for the soils of alluvial zones, the soils in arid and semi-arid regions where olive trees are growing are deficient in organic matter. This is a property of arid and semi-arid soils (El Hassani et al., 2023).

It is usually well demonstrated that organic farming has a good influence on soil quality and biodiversity (Calabrese et al., 2015). These studies and our results reveal that the positive impacts of intensive management practices and organic farming are also obvious in the case of olive groves.

Otherwise, the application of both methods (10 % of farms) offers high production, with the highest yield of 150 q/ha but a similar yield of 14.5 L/q in olive oil to the organic methods. Land-use management in olive groves is crucial for limiting soil erosion and land degradation (Kairis et al., 2013).

The traditional approach is connected with ancient or extremely old orchards, typically on terraces, and farmed with few or no agrochemicals.

The results of pruning show that 80 % of the surveyed farms demonstrated a preference for systematic pruning, with pruning intervals primarily falling within the 1 to 2-year range. In contrast, the remaining 20 % of farms practiced sporadic pruning with no fixed schedule.

Despite the fact that some farms (15 % of the study sample) use submersion irrigation, the majority of surveyed farms (85 %) use drip irrigation. All olive groves in this study are in irrigated agricultural areas. In rural areas, olive orchards utilize drip irrigation to effectively manage land and enhance livelihoods while also demonstrating resilience and conservation in line with agroecological concepts and to substitute rainfed olive farming.

In related references, it was observed that due to the combined impacts of temperature increase and reduced precipitation, rainfed olive farming might become unviable in the future, giving way to intensively irrigated olive orchards in wetter locations, with possible socio-economic and water redistribution repercussions (Tanasijevic et al., 2014).

Thus, the future of olive farming in the Mediterranean faces a huge challenge. Reconciling the sustainability of two conflicting growing systems, one concerns traditional olive groves in water-scarce locations, relying on minimum irrigation or rainfed systems. The other involves extensive orchards in wetter places, where larger water volumes can be employed for greater economic benefits.

The data obtained from the questionnaire indicates that all farms use a fully manual harvesting system, which might result in high labor costs due to the difficulty in finding specialized workers.

- ***Pests and diseases***

According to Figure 9, olive trees on farms are affected by pests and diseases. The significant problem is the Olive fly (Bactrocera oleae) which accounts for 36 % of the cases and is a concern for olive growers. The second common issue is Verticillium Wilt (Verticillium dahliae), with a prevalence of 18 %. However, it's important to note that "dwarfism" and "peacock eye" are not diseases associated with olive trees. To accurately identify these conditions, further clarification would be necessary. Additionally, olive psylla (Euphyllura olivina) Weevils (family Curculionidae) and snails (family Helicidae or Pulmonata) all have an occurrence rate of 9 %, indicating that they pose minor problems. But still warrant attention to prevent potential damage and maintain optimal olive tree health. The growers did not implement any pest or disease management practices.

Proper pest and disease management strategies should be employed to protect olive crops and ensure sustainable and productive olive farming.

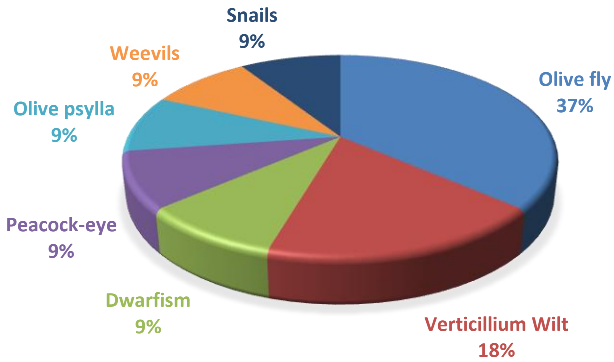

Fig. 9. The main pests and diseases in the surveyed olive groves

Processing of yield factors using PCA

We applied principal component analysis (PCA), as shown in Figure 10.

The initial cluster consists of young farms with little yield that are small-scale farms situated at high altitudes on moderate slopes. In contrast, the second group comprises farms with moderate to high altitudes and a gentle slope. The age of farms varies, but this group has relatively older farms. These farms are traditional small-scale ones with relatively good yields.

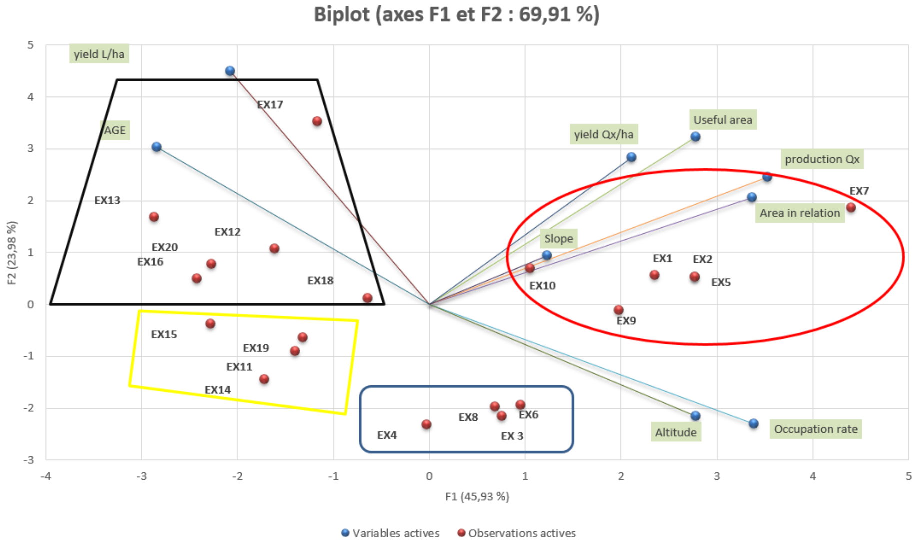

Fig. 10. Biplot of the first two principal components of olive trees factors

The third one includes farms with varying altitudes, but most have moderate to high altitudes. The slopes of the farms in this group also vary. These farms are relatively young in terms of age. This group encompasses more modern and intensive agricultural operations, benefiting from high yields and substantial production.

Finally, the fourth group comprises older farms with various slopes and relatively high altitudes. These farms are actively engaging in the development of sustainable agricultural practices.

We notice that the majority of Djelfa's olive grove farms (70 %) are involved in the development of sustainable agriculture; thus, the rest represent traditional small-scale farms. Also, the main olive grove farms in M'sila (70 %) are engaged in an intensive production system; the minority present young and small-scale farms.

In conclusion, Djelfa groves are primarily engaged in sustainable transition with some smaller traditional farms at varied elevations and slopes, in contrast to M'sila, which has a mix of intense, highly productive olive groves and smaller traditional farms. In Djelfa's higher elevations, the youngest, lowest-yielding farms are concentrated.

Consequently, olive groves may be classed into two broad groups depending on their management practices: (1) strongly maintained conventional olive groves and (2) extensively managed traditional (primarily organic) olive groves (Amvrazi and Albanis, 2009).

CONCLUSIONS

The study's conclusions allowed us to make the following notes:

In the climate of Djelfa, rainfall is a limiting factor for olive yields, although temperature has less of an impact. In contrast, neither temperature nor rainfall significantly limit yields in the M'sila climate.

In both provinces, higher altitude (> 600 m) orchards produced more olive oil than lower altitude (600 m) groves, indicating that higher altitudes are more suitable for producing olives.

In no province were any appreciable relationships between slope and yields discovered.

In both provinces, larger and older olive groves produced better yields, which is indicative of the advantages of economies of scale.

Compared to monocultures, intercropping often resulted in lower olive yields in both regions.

In both provinces, the use of chemical fertilizers was linked to higher olive oil yields than organic fertilization.

In M'sila, yields may be lower than in Djelfa because of older farmers on average and less access to subsidies. Some farmers have the opportunity to improve practices and yields through training programs because they have higher levels of knowledge.

Summing up the results, it can be concluded that younger individuals with higher levels of education and agricultural training, as well as areas with gentle slopes and higher altitudes, are important factors for successful olive plantations in steppe lands. Additionally, government support through subsidies, land tenure laws, and policies can contribute to enhancing olive grove production. Direct financial assistance and ownership of their farms can create a more comfortable and trustworthy environment for farmers.

It is recommended that these factors be considered, along with the adoption of organic and biological management practices, as an effective strategy for improving the sustainability of olive production systems in arid and steppe areas, as well as for continuing to expand olive cultivation to new and promising regions.

Acknowledgment

The authors express gratitude to the olive growers for granting us permission to take part in this questionnaire. We further extend our appreciation to the management personnel from the two agricultural service directorates in Djelfa and M’sila for their aid and for furnishing us with the requisite information for this research.

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Received:	Revised:	Accepted:	Published:
September 03, 2023	November 02, 2023	November 08, 2023	November 30, 2023