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NOTE AND COMMENT

Dinner is served: how climate change interferes with olive oil production

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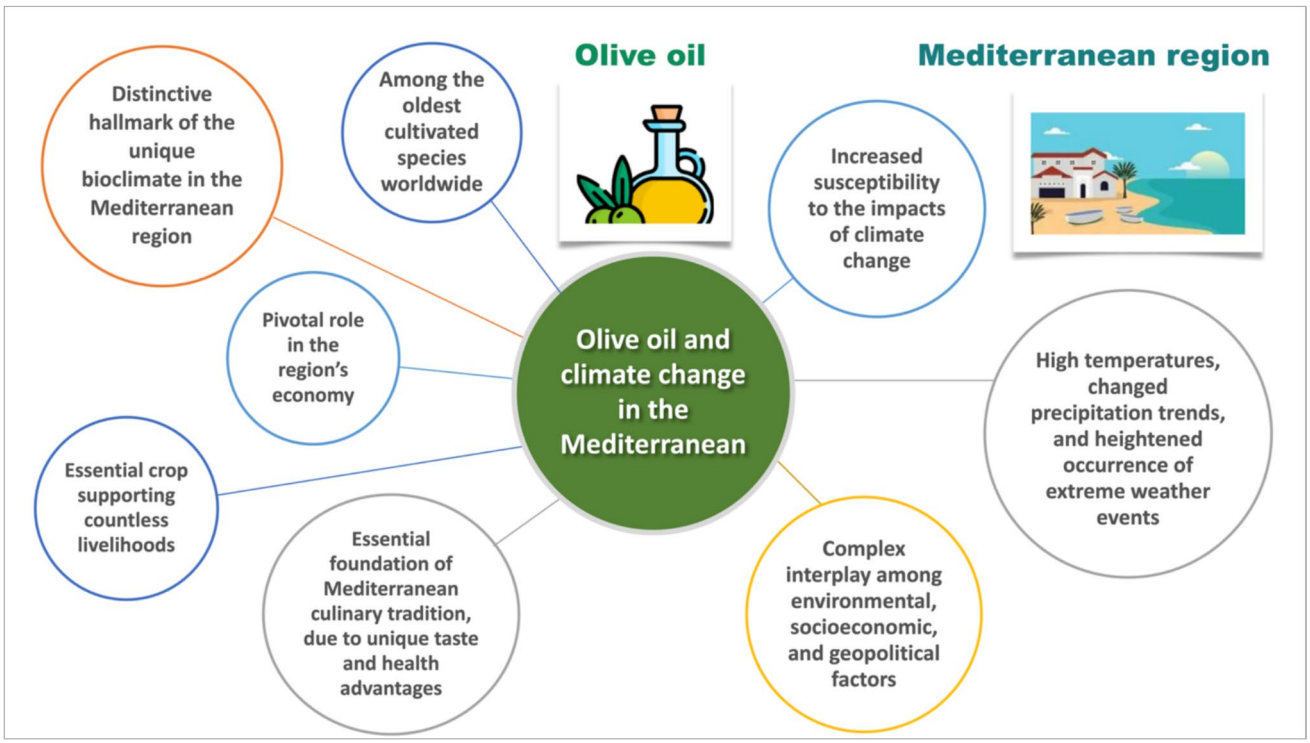
Abstract

The Mediterranean region accounts for nearly 95% of global olive oil production. However, climate change—manifesting in intensified heatwaves, prolonged droughts, and increased pest prevalence—is undermining both the quantity and quality of yields. These disruptions threaten the livelihoods of rural producers and destabilize international markets. This article examines the complexities facing growers and outlines targeted mitigation strategies, highlighting the broader implications of climate change for a staple commodity relied upon daily by millions around the world. The analysis highlights interconnected climate impacts on agriculture, trade, and gastronomy, and identifies opportunities to enhance resilience through policy, agronomic innovation, and sustainable practices. It advances an integrated approach to Mediterranean food sustainability, linking agricultural adaptation with culinary heritage.

Graphical abstract



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Article highlights

- Climate change threatens Mediterranean olive oil production and endangers traditional farming livelihoods.
- Volatile yields and rising costs disrupt global olive oil markets.
- Gastronomic adaptation to olive oil price surges reshapes culinary practices.
- Sustainable farming and innovation offer pathways to resilience through climate-smart agriculture, water-efficient irrigation, and drought-resistant olive varieties.
- Coordinated policy interventions must support climate adaptation in olive farming, incentivise sustainable practices, and enhance farmers' resilience.

Keywords Olive oil production · Climate change adaptation · Mediterranean agriculture · Food system resilience · Agroecological innovation · Culinary heritage · Agricultural trade

Introduction: climate change and olive cultivation in the Mediterranean

Climate change profoundly impacts the Mediterranean region, a hotspot for environmental and socioeconomic effects. This region, characterized by its unique climate and biodiversity, is experiencing significant alterations in weather patterns and climate (Sarkar et al. 2022). One of the most evident impacts is the rise in average temperatures. The Mediterranean has warmed by 1.4 °C since the late nineteenth century, a rate higher than the global average (Pisano et al. 2020; Wedler et al. 2023). This warming is causing more frequent and intense heat waves, threatening human health and straining energy and water resources (Wedler et al. 2023). The agricultural sector is particularly vulnerable, as increased temperatures and prolonged droughts reduce crop yields, disrupt planting seasons, and elevate the risk of wildfires. These conditions threaten food security and the livelihoods of farmers (Graus et al. 2024; Zagaria et al. 2023). Importantly, in the Mediterranean region—a major center of olive cultivation and the primary focus of this paper—rising temperatures and water scarcity are significantly reducing both the quantity and quality of olive yields (Fraga et al. 2020), exacerbating production volatility. Increasing average temperatures disrupt the growth cycles of olive trees. Extreme heat during flowering lowers pollination success, resulting in fewer fruits (Nissim et al. 2020). Long heatwaves speed up ripening, causing olives to shrink and reducing their oil content. Additionally, warmer winters do not provide enough chilling hours necessary for proper bud development, which further lowers yields.

The Mediterranean is also experiencing changes in precipitation patterns, including more frequent and severe drought, water scarcity, reduced rainfall, and increased evaporation rates, leading to diminished water availability (Tramblay et al. 2020). This scarcity affects both drinking water supplies and irrigation, exacerbating tensions over water resources and impacting agricultural productivity (Gaaloul et al. 2021). Moreover, the reduction in freshwater inflow to rivers and wetlands threatens ecosystems and biodiversity, leading to the loss of habitats and species (Martínez-Megías and Rico 2022). Water shortages and increasing temperatures significantly influence agriculture and olive oil production in the Mediterranean (Tanasijevic et al. 2014). These impacts—both direct and indirect—affect yield, production processes, and the economic viability of olive farming (Maesano et al. 2021; Ouessar 2017). Olive trees, while drought-resistant, still need enough water during key growth stages. Lack of rainfall and drained groundwater supplies stress the trees, leading to smaller and fewer fruits (Brito et al. 2019). Regions that rely on irrigation face disputes over water, which raises production costs. Also, water stress changes the composition of olive oil, decreasing beneficial polyphenols and increasing acidity, which lowers its market value. Overall, rising temperatures and water shortages caused by climate change threaten the future of olive farming in the Mediterranean (Kaniewski et al. 2025; Tanasijevic et al. 2014).

This study pursues three objectives: first, to analyze how climate change and shifting Mediterranean growing seasons are reshaping olive production dynamics and threatening the cultural identity tied to this crop; second, to review emerging adaptation strategies—including drought-resistant varieties, precision irrigation, agroforestry, and technological innovations—and to consider their potential to safeguard yields and farmer livelihoods; and third, to assess the wider socioeconomic implications of declining and volatile productivity for global olive oil supplies, international markets, and Mediterranean regional economies.

Drawing on diverse datasets from across the Mediterranean, the analysis demonstrates how changing growing seasons are transforming not only production dynamics but also the cultural identity of this iconic crop. Adaptation measures, such as drought-resistant varieties, efficient irrigation,

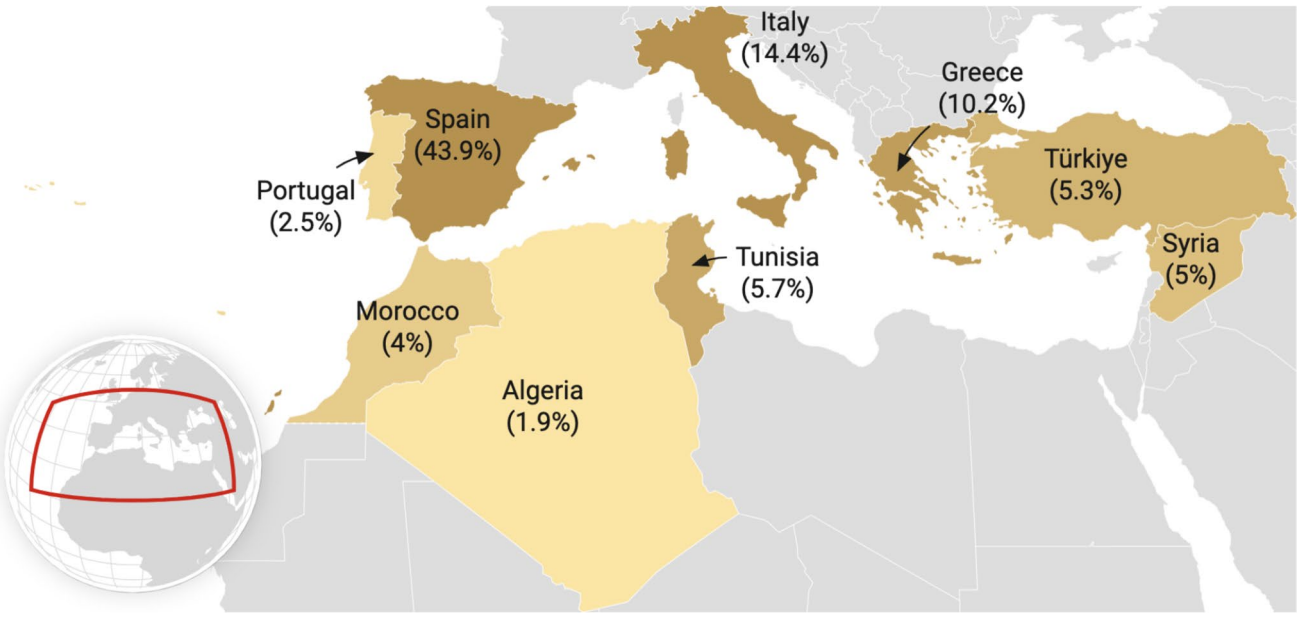

Fig. 1 Top 9 producer countries and their share in world olive oil production (2017–2020). Spain, Italy, and Greece together account for more than two-thirds of global olive oil production, underscoring the Mediterranean's central role in global supply. Data source: International Olive Oil Council (IOC). (Figure by authors, created with Datawrapper)

and agroforestry, are shown to be important for protecting this agricultural product and sustaining rural livelihoods. Without effective action, declining yields risk undermining global olive oil supplies and destabilizing regional economies. By offering actionable insights for both policymakers and producers, the paper contributes to bridging agronomic adaptation with culinary heritage, advancing an integrated approach to sustainability in Mediterranean food systems. The following sections examine these objectives in turn, beginning with the impacts of climate change on olive oil production in the Mediterranean.

Impacts of climate change on olive oil production

Climate change impacts on olive yields

The olive tree, scientifically known as *Olea europaea L.*, is one of the oldest cultivated species globally, symbolizing cultural identity and standing as a quintessential emblem of the Mediterranean region (Ben Hmida et al. 2022). This region is the world leader in olive cultivation and olive oil production (Araújo et al. 2019, 2021), accounting for the lion's share of global production (Fig. 1). Beyond its botanical significance, the olive tree is a hallmark of the Mediterranean's unique climate and culinary heritage, cherished for its distinctive flavors and nutritional benefits (Kaniewski et al. 2023). Despite spread of olive trees across various microclimates globally, approximately 95% of olive oil production occurs within Mediterranean nations, with Spain, Italy, Greece, and others being primary producers (Anania and Pupo D'Andrea 2011; Ben Hmida et al. 2022; Ouessar 2017).

In terms of cultural significance, the olive tree and its oil are deeply interlinked with Mediterranean societies, functioning as emblems of peace, prosperity, and longevity that anchor collective identities and shared traditions. Their influence extends beyond agriculture, shaping landscapes, rituals, and collective memory while permeating daily life. Olive cultivation practices, often passed down through generations, embody a rich artisanal heritage that fosters strong community bonds and reinforces regional identities. In culinary terms, olive oil is not merely an ingredient; rather, it is a foundational element that defines the region's gastronomy, influencing cooking methods, flavor profiles, and eating habits. This cultural importance means that disruptions to olive oil production pose threats extending beyond economic impacts, compromising a cherished way of life and a defining aspect of Mediterranean heritage. In this sense, olive oil operates as a cultural medium that conveys history, values, and social cohesion across the region (Meneley 2020; Mili & Bouhaddane 2021; IOC 2022).

The Mediterranean Basin, a focal point of climate change impacts and labeled a 'hotspot' by the Intergovernmental Panel on Climate Change (IPCC) (Ali et al. 2022), faces significant challenges. Climate change increasingly affects olive oil production (Orlandi et al. 2020; Rodríguez Sousa et al. 2020; Santos et al. 2016). Drought stress, rising temperatures, and heatwaves adversely impact olive yields (Ben

Zaied and Zouabi 2016; Brito et al. 2019; Fraga et al. 2020), with repercussions echoing throughout the Mediterranean economy. Fraga et al. (2019) project yield declines of up to 45% in primary production areas, underscoring substantial vulnerabilities. Recent studies have corroborated these concerns, identifying comparable climate-related risks. The European Commission's Directorate-General for Agriculture and Rural Development (DG AGRI) has reported significant downturns in the olive oil and table olive sectors (European Commission 2023). This decline has impacted major producers, such as Greece, Spain, and Italy—threatening farmers' livelihoods, disrupting supply chains, and contributing to inflationary pressures as well as broader economic and social instability. The impact of climate change on olive oil production thus transcends agricultural concerns, linking directly to economic stability, livelihood security, and regional sustainability (Sevim et al. 2023).

Economic and societal impacts

From 2021 to 2024, the Mediterranean region—particularly Spain, Portugal, Italy, and Greece—experienced lower and irregular rainfall patterns, droughts, and heatwaves that significantly impacted olive oil production. These changes forced producers to adapt quickly and highlighted the industry's resilience and adaptability. Farmers faced higher costs as they responded to changing conditions, including investing in irrigation systems and new olive varieties that are more resilient to climate change (Kaniewski et al. 2023; FWS 2024; Rodrigo-Comino et al. 2021). Global olive oil production fell from 3.42 Mt in the 2021–22 season to 2.57 Mt in 2022–23 and dropped further to 2.41 Mt in 2023–24. This represented a 26% decline in global production compared to the preceding marketing year (2022–23), and a 23% drop relative to the 5-year average (Statista 2024; FWS

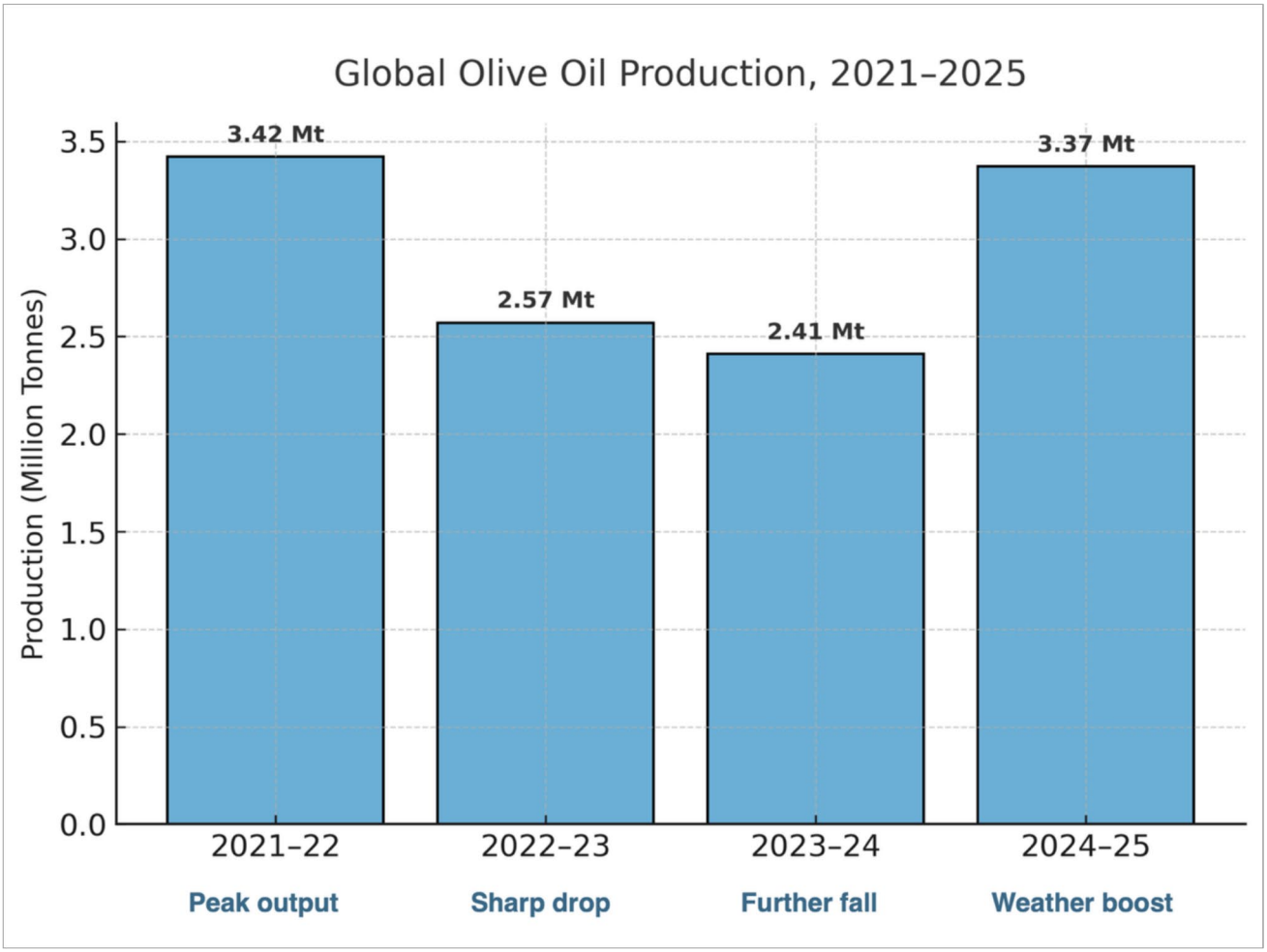

Fig. 2 Global olive oil production, 2021–2025 (in million tons). Data source: International Olive Oil Council (IOC). Production peaked in 2021–22, dropped sharply in 2022–23 and 2023–24, and partially recovered in 2024–25 due to favorable weather conditions. (Figure by authors)

2024). In 2024/25, production is rebounding toward 3.4 Mt, driven by recovery in Mediterranean producers (TRIDGE 2024), representing a 32% increase in world production to 3.37 Mt in 2024/25—largely due to a 48% recovery in Spain to around 1.26 Mt (OOWC 2024; Reuters 2024), along with gains in Greece (OOWC 2024; TRIDGE 2024) and Portugal (Reuters 2024). Figure 2 illustrates these trends.

The main reason why Mediterranean olive oil production increased significantly in 2024/25 was the return of better weather patterns. There was enough rain in spring, and there were no extreme heatwaves during the important flowering period (Reuters 2024). This helped the hardy olive trees, which had been resting and saving energy during earlier poor harvests, enter a strong natural production cycle. The better conditions led to successful flowering and fruit set, resulting in a much-needed recovery in output across major producing areas (OOWC 2024; Reuters 2024). Although this recovery delivered temporary relief and much-needed output across key producing regions, it appears to stem from short-term climatic variability rather than any lasting structural change (Kaniewski et al. 2025; European Commission 2023). Therefore, it cannot yet be interpreted as the direct outcome of long-term adaptation strategies, and the broader declining trend linked to climate stress remains a pressing concern (Fraga et al. 2019; Ouessar 2017). Despite short-term fluctuations, the underlying trajectory points to increasing climate sensitivity and long-term agricultural vulnerability, necessitating proactive and sustained adaptation efforts (Kaniewski et al. 2025).

Following repeated calls for adaptive measures (Ouessar 2017; Ozdemir 2016), recent supply pressures have significantly increased production costs and, correspondingly, olive oil prices. Over the period 2021–22, prices rose considerably due to lower production yields caused by unfavorable weather. After steady cost increases from 2021 to 2023, the price surge accelerated in the second half of 2023, and by October 2023, prices were approximately 50% higher than in October 2022 (Eurostat 2024). Continuing this trend, by January 2024, the price of olive oil in the EU was 50% higher than in January 2023, primarily due to drought and heat waves, particularly in Spain, Portugal, and Greece (Eurostat 2024; Food Navigator Europe 2024). For instance, in Jaén, Spain, the extra virgin olive oil price was €794.5 per 100 kg in June 2024, a 23.2% increase from the same period in 2023. Both supply constraints and rising demand have influenced these price increases. As a major producer of olive oil, the Mediterranean region has acutely felt the impact of these changes (IOC 2022, 2024a; b).

The effects of climate change on olive oil production span physical, economic, and cultural domains, contributing to sector-wide volatility. The current changes disrupt long-standing traditions, destabilize rural communities, and reshape global trade. As yields decrease, farmers of small landholdings struggle financially. In contrast, larger producers gain market control, raising prices and changing consumption habits. The decline in premium-quality oil threatens Mediterranean food heritage, reducing the cultural significance of artisanal production (Mili and Bouhaddane 2021). Moreover, unstable supply chains create market volatility, affecting exporters and consumers around the globe. Thus, the impacts of climate change on olive oil production extend beyond agriculture, with far-reaching consequences for socioeconomic stability and cultural identity in olive-growing regions.

Adapting olive cultivation to climate change

Gastronomic and culinary adaptations

Sustained rises in olive oil prices may impact the gastronomy sector, particularly in regions that are culinary tourist destinations and attract "olive oil tourism (Oleotourism)" (Dancausa-Millan et al. 2022, p. 2; Tregua et al. 2018). Restaurants that rely heavily on olive oil as a staple ingredient, pizzerias, and gourmet establishments specializing in Mediterranean cuisine may be constrained to adjust their operations and menu offerings in response to continuing market price rises (Cramer et al. 2018; Ponti et al. 2014). One possible strategy may be identifying cost-effective alternatives without compromising culinary quality or cultural authenticity (Dancausa-Millan et al. 2022; Fraga et al. 2019; 2020). For example, restaurants may incorporate blends of olive oil with other vegetable oils like sunflower or canola oil to mitigate costs while at the same time maintaining flavor profiles and adhering to Mediterranean culinary traditions, palates, and imaginaries (Maesano et al. 2021; Meneley 2020; Sevim et al. 2023). Moreover, the industry may follow

Fig. 3 Olive oil as a cultural and culinary staple in the Mediterranean diet. Olive oil is not merely an agricultural product but a foundation of Mediterranean cuisine, symbolizing deep ties between farming, food heritage, and cultural identity (Image: Adobe Stock, licensed.)

general sustainability trends toward sourcing locally produced olive oils and promoting lesser-known varieties that may be more affordable and subject to lower demand pressures (Dancausa-Millan et al. 2022; Tregua et al. 2018). This may help manage costs while at the same time supporting local producers and adding a unique element to the culinary experience by catering to a broad spectrum of preferences and tastes (Sevim et al. 2023). Finally, restaurants may resort to the use of alternative oils, such as avocado or grapeseed oils, which, although sometimes more expensive, may offer distinct flavors and health benefits that can justify their inclusion in Mediterranean dishes suited to local customs and palates (Dancausa-Millan et al. 2022; Meneley 2020).

The appreciation of olives, especially through high-quality oil, goes beyond culinary trends. It reflects a strong commitment to cultural and environmental resilience, directly benefiting human well-being and enriching national cultural identity. By turning the olive from a simple ingredient into the focus of tasting experiences, the value of food is significantly boosted (Pulido-Fernández et al. 2022). This change promotes slower, mindful eating, allowing citizens to enjoy the complex flavors of a single-origin oil. It also fosters a deeper connection to food and supports health by valuing quality over quantity (Fig. 3).

This careful appreciation also encourages the protection of ancient, drought-resistant olive groves. These trees may yield less fruit, but they are more genetically diverse and better suited to a changing climate than intensive monocultures. By making these traditional cultivars financially viable through premium experiences, a contribution to the protection of agricultural biodiversity is made. This diversity acts as a buffer against climate change (The Parliament 2024) and ensures a wider gene pool of resilient trees, which is vital for future food security.

Additionally, this focus on food helps preserve intangible cultural heritage. It keeps alive the knowledge of different cultivars, terroirs, and traditional milling techniques passed down through generations. It positions farmers as stewards of the land, fighting desertification while sustaining the Mediterranean ecosystem. Therefore, choosing a quality dining experience centered on authentic olive oil becomes a conscious decision to engage in a sustainable food system. It forges a link between personal health and planetary health, underscoring that a diverse, flavorful, and culturally rich diet supports both environmental resilience and human well-being. This creates a positive cycle that benefits people and the earth alike.

These efforts may be coupled with educational initiatives that raise awareness among locals and tourists alike and inform consumers about the reasons behind price adjustments, olive oil varieties and blends, and the properties, qualities, and tastes of available alternatives (Sevim et al. 2023). Transparency in sourcing, linked to a sustainability and local support narrative, may also maintain consumer trust and satisfaction (Tregua et al. 2018). By adapting creatively, responsibly, and proactively, the gastronomy sector may navigate the economic challenges of olive oil price pressures while at the same time continuing to deliver quality dining and degustation experiences (Dancausa-Millan et al. 2022; Pulido-Fernández et al. 2022).

Genetic, agronomic, and technological adaptations

Adaptation measures can be understood in terms of their degree of maturity and diffusion. Some are already widely adopted and demonstrating clear benefits, while others are emerging or still experimental, facing barriers to implementation. Organizing the discussion in this way highlights not only the diversity of options but also the interconnections among them.

Selecting drought-resistant olive varieties is a key adaptation strategy. ‘Chemlali’ and ‘Koroneiki’, for example, perform well under arid conditions while maintaining high oil quality (Fraga et al. 2020; Brito et al. 2019). Their deeper root systems and efficient water use make them particularly resilient during prolonged dry periods. These genetic and agronomic measures, already applied at scale in several Mediterranean countries, demonstrate how innovation and resource efficiency can reinforce one another in practice. Another key strategy is precision irrigation, which delivers controlled amounts of water directly to olive tree roots through drip systems. This approach minimizes water waste and ensures adequate moisture during critical growth stages (Tanasijevic et al. 2014; Gaaloul et al. 2021).

Other approaches are gradually expanding, often through research projects and regional initiatives, but they are not yet widespread. Soil management is also essential for reducing climate stress. Using cover crops like legumes or grasses in support of olive plants helps retain moisture, prevents erosion, and increases organic matter, which improves water retention in areas prone to drought (Ouessar 2017; Zagaria et al. 2023). Additionally, mulching with organic materials, such as straw or olive pomace, cuts down on evaporation, keeps soil temperatures steady, and limits weeds that compete for water. Agroforestry systems can enhance olive tree resilience by integrating nitrogen-fixing or shade-providing species, helping farmers create favorable microclimates. Local adaptation strategies may also include establishing windbreaks to protect against storms and constructing reservoirs for water storage. Such site-specific ecological interventions can help moderate the effects of extreme heat and wind and promote healthier tree growth and improved productivity.

Pruning techniques that suit warmer climates can help reduce stress on olive trees. Thinning branches improves air flow, lowers the risk of disease in humid conditions, and

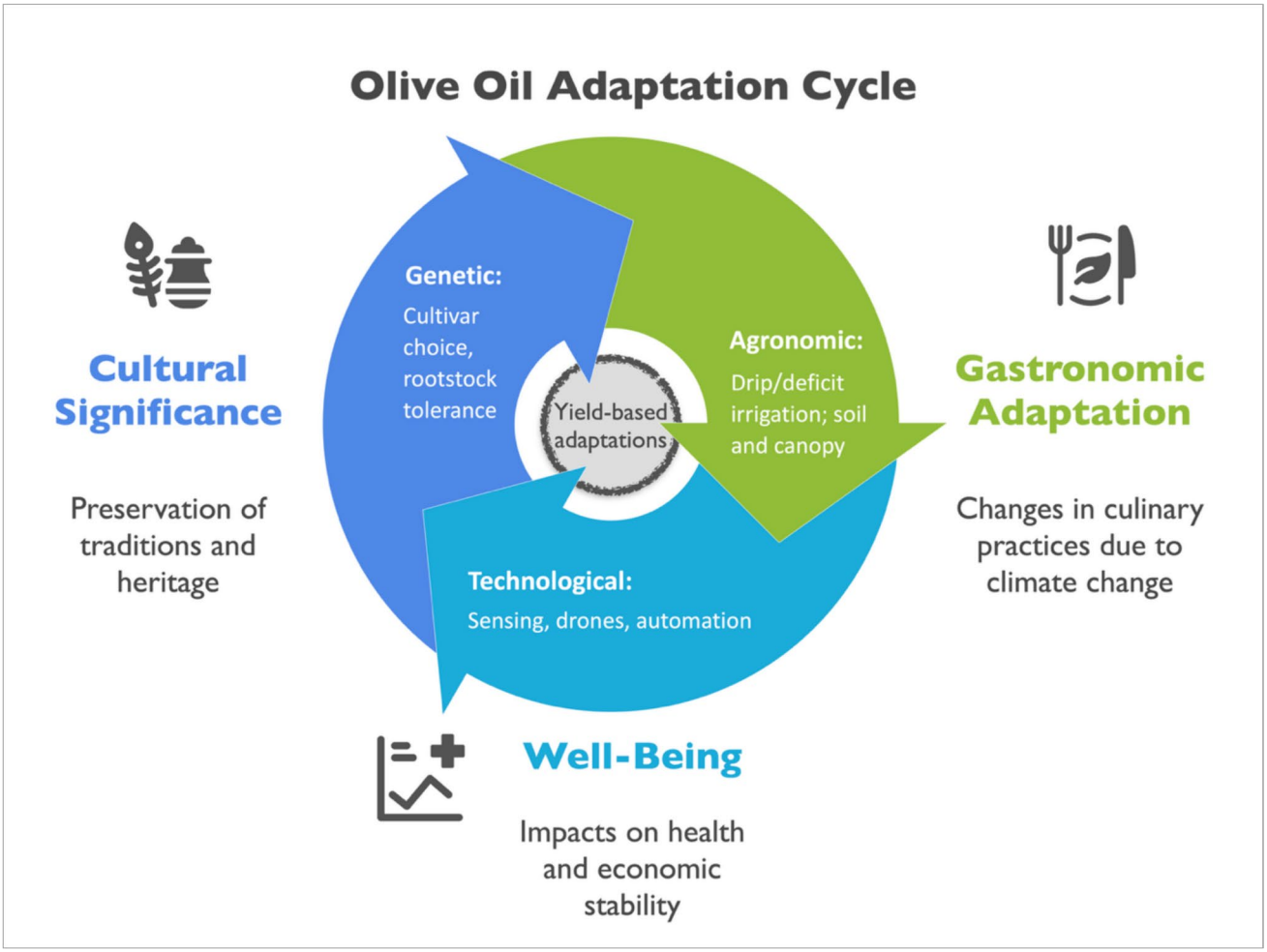

Fig. 4 The olive oil adaptation cycle, illustrating the interconnected dimensions of cultural significance, gastronomic adaptation, and well-being under climate change. The cycle shows how preserving traditions, adapting culinary practices, and safeguarding health and economic stability form mutually reinforcing elements of resilience in Mediterranean olive oil systems. The arrow labels within the cycle position genetic, agronomic, and technological yield-based adaptations that sustain production (see the section "Genetic, agronomic, and technological adaptations"). (Figure by authors)

promotes balanced fruit production. This prevents trees from struggling during water shortages. Adjusting harvest timing is another critical adaptation strategy. Harvesting earlier in warmer years can prevent over-ripening and oil degradation, helping to preserve acidity levels and phenolic content (Nissim et al. 2020; Kaniewski et al. 2025).

Further strategies remain at an earlier stage or face practical constraints, including costs, technical expertise, or policy support. Nevertheless, they are crucial for long-term resilience. As climate change intensifies pest and disease outbreaks, integrated pest management (IPM) provides a sustainable and effective response. This lessens reliance on chemicals while keeping trees healthy. Beneficial insects, pheromone traps, and resistant rootstocks can help manage pests like the olive fruit fly, which flourishes in warmer weather (Orlandi et al. 2020; Sevim et al. 2023). Adopting solar and other renewable energy sources in olive mills helps reduce the environmental impact of olive oil production (Maesano et al. 2021).

Leveraging technology is another essential strategy for managing climate risks in olive cultivation. Precision agriculture tools—such as drones and soil sensors—enable real-time monitoring of moisture levels, early detection of pest infestations, and enhanced assessment of grove health (Rodríguez Sousa et al. 2020; Kaniewski et al. 2023). These technologies support data-driven decisions and targeted interventions, helping to minimize the adverse impacts of climate change.

Finally, equipping farmers with climate education and timely access to forecasts empowers more informed decision-making. Early warnings of heatwaves and droughts allow for proactive responses, such as deploying shade nets

or activating emergency irrigation. Government and industry investment in research—particularly into heat-tolerant olive varieties and sustainable cultivation practices—will be crucial for long-term resilience (The Parliament 2024; Ozdemir 2016). Awareness campaigns can further support growers by highlighting the benefits of adopting innovative methods and technologies. Together, these diverse strategies can help mitigate the impacts of climate change and secure the future of this historic and culturally significant crop.

Overall, there is considerable evidence that research on olive grove resilience associated with Mediterranean climate change remains largely in its infancy and that more work is needed to safeguard effective and enduring adaptation (Cramer et al. 2018; Dancausa-Millan et al. 2022; Ouessar 2017; Rodríguez Sousa et al. 2020). At the same time, the analysis presented here indicates that adaptation strategies are most effective when understood as elements of a broader cycle that links cultural significance, gastronomic practices, and socioeconomic well-being (see Fig. 4).

Concluding remarks

Climate change poses serious challenges to olive farming, with rising temperatures, unpredictable rainfall, and extreme weather threatening both yields and oil quality. Yet, olive farmers and associated sectors can implement a range of strategies to adapt. Efficient resource management and adaptive farming practices can sustain production while preserving the quality and tradition of Mediterranean olive oil. Such measures help safeguard livelihoods and maintain the cultural, culinary, and environmental heritage of olive cultivation for future generations. Adaptation strategies—whether established, expanding, or still emerging—are most effective when combined, rather than applied in isolation. These include genetic measures, such as drought-resistant varieties, agronomic practices like precision irrigation, soil management, and agroforestry, and technological innovations, such as precision agriculture tools and renewable energy integration.

This article has shown how climate change is reshaping olive production in the Mediterranean, with consequences spanning agronomic, economic, and cultural domains. Addressing these challenges requires an integrated adaptation strategy that combines locally tailored practices, technological innovation, and coordinated policy responses. By synthesizing regional climate data, agronomic evidence, and socioeconomic considerations, the paper contributes a holistic perspective to the literature on climate-resilient food systems. It highlights the value of bridging agronomy and gastronomy—not only to secure yields and livelihoods, but also to sustain the cultural and culinary heritage embedded in Mediterranean olive cultivation. By integrating agronomic evidence with cultural and socioeconomic perspectives, the paper supports efforts to future-proof olive farming against climate risks while reaffirming and safeguarding its enduring role in local Mediterranean economies and global food culture.

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Author contributions Following CRediT (Contributor Roles Taxonomy), the authors declare their contributions to this research as follows: conceptualization, WLF; data curation, WLF, JML, MAPD, and GJN; formal analysis, WLF, JML, MAPD, and GJN; funding acquisition, JML; investigation, WLF, JML, MAPD, and GJN; methodology, WLF, JML, MAPD, and GJN; resources, JML; visualization, JML and MAPD; writing—original draft, WLF, JML, MAPD, and GJN; writing—review and editing, WLF, JML, MAPD, and GJN. All authors have equally contributed to writing this short communication.

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Data availability The authors declare that all data supporting this study are available within the paper. Data sources that underpin Figs. 1 and 2 have been provided in the captions.

Declarations

Conflict of interest The authors declare no competing interests.

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