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**From Orchard to Global Market: A Comprehensive  
Analysis of California's Almond and Pistachio Industries**

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**Abstract.**

*California is a critical player in the global almond and pistachio markets, producing over half of the world's almond supply and 99% of the U.S. pistachio production. This paper examines the state's unique contributions to these industries, highlighting their growth, sustainability practices, and future projections. Over the past two decades, almond acreage has expanded from 0.5 million to 1.37 million acres, while pistachio acreage has grown from 75,000 to 462,000 acres. Despite recent declines in farm prices from their peaks in 2014, the demand for these nuts continues to drive forecasts of increasing prices, supported by sustainable farming practices and technological innovations such as AI and precision agriculture. Almond farmers have significantly reduced water usage through micro-irrigation, contributing to a 33% reduction in water needed per pound of almonds over 20 years. Pistachio growers have adopted strategies to combat pest pressures and enhance yield quality, resulting in record harvests and expanding export markets. The paper also explores the impact of environmental regulations, labor laws, and climate conditions on price stability and production cycles. Through analysis of historical data and future projections, this study offers a comprehensive overview of the current state and future potential of California's almond and pistachio industries. Their commitment to innovation and sustainability ensures their pivotal role in the global market. Future research will assess the impact of precision agriculture technologies on enhancing productivity and sustainability.*

**Keywords.**

*California agriculture, almond and pistachio production, sustainability practices.*

## I. Introduction

California plays a crucial role in the global production of both almonds and pistachios, thanks to its unique Mediterranean climate. The state is home to over 50% of the world's almond supply, with 7,600 almond farms, 90% of which are family-owned (FAO-STAT, 2024, Almond Board of California, 2024). Many of these farms are operated by third- and fourth-generation farmers who plan to pass the land down to future generations. Since 1973, almond farmers have invested around \$10 million annually in scientific research to support on-farm innovation, market the health benefits of almonds, and create new value from almond co-products. These practices also contribute to the industry offsetting about 50% of its carbon emissions and making California the most productive (high-yield) almond grower.

Water sustainability is a priority for almond farmers, who are exploring methods to replenish underground aquifers through on-farm groundwater recharge. The adoption of water-saving technologies like micro-irrigation has helped reduce the water required to grow one pound of almonds by 33% over the past 20 years. New artificial intelligence (AI) technologies, farm robots, driverless equipment, drones, and GPS surveillance created a new paradigm of sustainable tree nuts farming (Asci and Devadoss, 2021). These efforts are supported by the California Almond Stewardship Platform (CASP), which educates participants about sustainable farming practices and continuous improvement.

Pistachio production has also seen impressive growth, with California representing 99% of U.S. production. The state's 2022 crop was initially projected to surpass 1 billion pounds but ended up at approximately 875 to 885 million pounds due to varying challenges such as extreme heat during bloom and reduced irrigation due to drought. Nonetheless, the industry is poised for significant growth, with projections indicating that pistachio production could reach over 1.5 billion pounds by 2026 and potentially 2 billion pounds by the end of the decade.

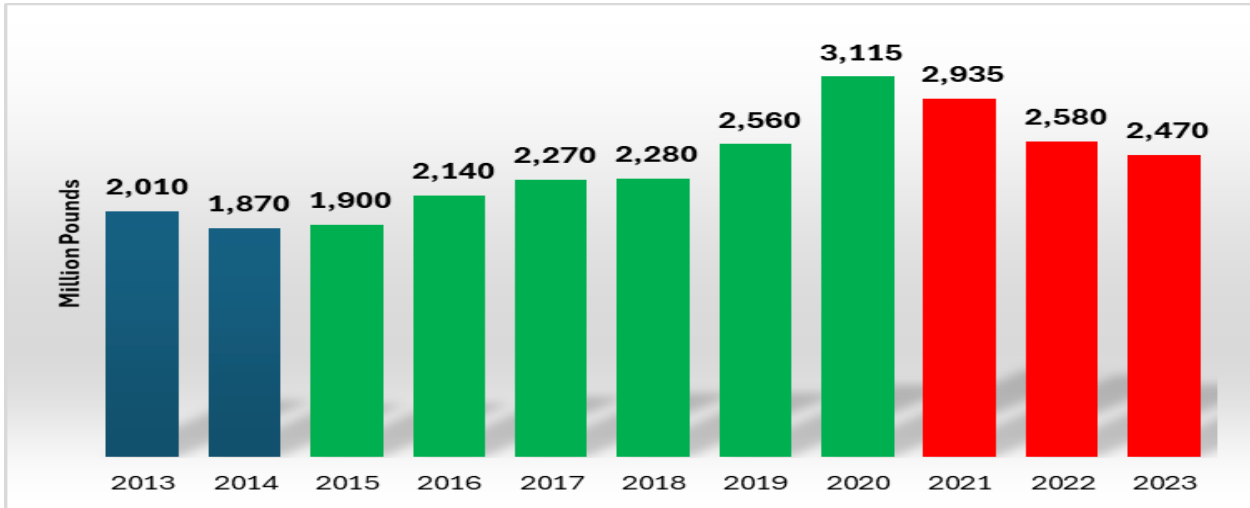
The 2023 pistachio harvest saw a record 1.49 billion pounds harvested, surpassing initial expectations of 1.3 billion pounds. Growers reported lower insect damage at the start of the season, though it increased as the season progressed, partly due to neighboring almond orchards facing challenges such as Navel Orangeworm (NOW). Pistachio growers have adopted strategies to reduce NOW populations, including precision agriculture techniques, winter orchard sanitation, proper timing of crop protection materials, and mating disruption techniques. These efforts have resulted in a decrease in NOW damage and higher percentages of closed-shell nuts, though growers with the Golden Hills variety reported higher amounts of open-shell pistachios. Harvesting of the Golden Hills variety began in mid-August, followed by the traditional Kerman variety from September through October (American Pistachio Growers, 2024).

In summary, both the almond and pistachio industries in California are marked by continuous innovation and sustainability efforts. While challenges such as drought, heat, and pest pressures persist, the commitment of these industries to sustainable practices and ongoing research ensures their continued success and resilience.

The rest of the paper is organized as follows. In Section II, we present the California almond production. In Section III, we discuss the California pistachio production before presenting our conclusion in Section IV.

## II. California Almond Production

The 2020 crop year saw a production of 3.1 billion pounds, making it the largest crop on record. Statewide average yield returned to a more typical 2,492 lbs./acre during this period (Figure 1).



Source: CDFA, 2024.

Figure 1. Almond Production in California (Shelled basis).

The USDA National Agricultural Statistics Service (CDFA, 2024) estimated that the 2023 almond crop being harvested in California's Central Valley yielded approximately 2.5 billion pounds. This forecast represents a 21% decrease from the 2020 crop. The projection is based on an estimated 1,370,000 bearing acres, which is an increase from 1,250,000 acres in 2020. The average nut set per tree for 2023 is estimated to be less than 4,000, which is about 20% lower than that of the 2020 crop.

### A. California Almond Acreage and Crop Value

Table 1 shows California's almond acreage, encompassing both bearing and non-bearing acres, as well as new acreage planted from 2012 to 2023. Crop values are reported as returns per pound, according to data from the USDA National Agricultural Statistics Service (USDA-NASS), and are also presented as returns per acre for growers.

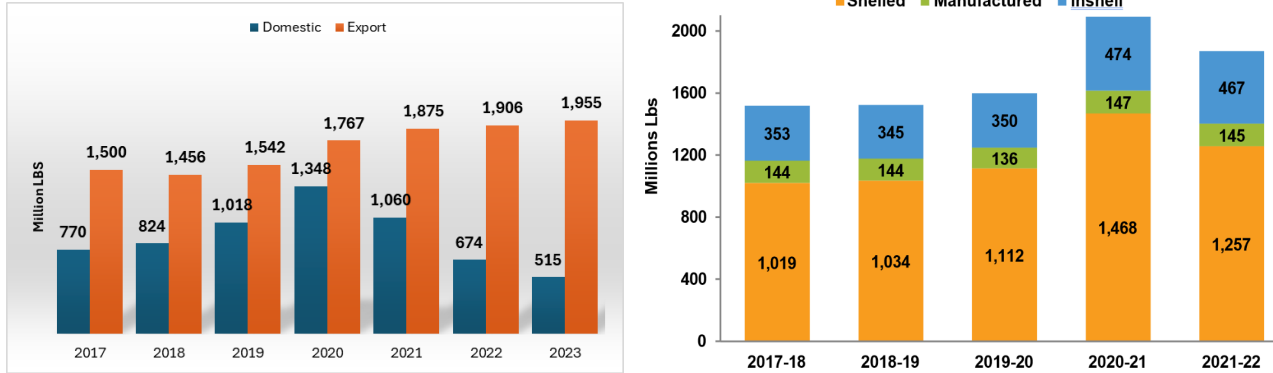
Table 1. California Almond Acreage and Farm Value.

YEAR	ACREAGE			YIELD		VALUE		
	BEARING	NON-BEARING	TOTAL	BEARING YIELD LB / ACRE	PRODUCTION MILLION LBS	FARM PRICE \$ / LB	FARM VALUE MILLION \$	VALUE PER ACRE
2012	820,000	110,000	930,000	2,310	1,890	\$2.58	\$4,817	\$5,874
2013	880,000	120,000	1,000,000	2,280	2,010	\$3.21	\$6,385	\$7,255
2014	930,000	170,000	1,100,000	2,010	1,870	\$4.00	\$7,388	\$7,944
2015	950,000	240,000	1,190,000	2,000	1,900	\$3.13	\$5,869	\$6,178
2016	970,000	300,000	1,270,000	2,210	2,140	\$2.39	\$5,052	\$5,209
2017	1,030,000	330,000	1,360,000	2,200	2,270	\$2.53	\$5,604	\$5,441
2018	1,090,000	300,000	1,390,000	2,092	2,280	\$2.50	\$5,603	\$5,140
2019	1,180,000	340,000	1,520,000	2,169	2,560	\$2.45	\$6,169	\$5,228
2020	1,250,000	350,000	1,600,000	2,492	3,115	\$1.71	\$5,251	\$4,201
2021	1,310,000	320,000	1,630,000	2,240	2,935	\$1.86	\$5,351	\$4,085
2022	1,350,000	290,000	1,640,000	1,911	2,580	\$1.40	\$3,536	\$2,620
2023	1,370,000	190,000	1,560,000	1,803	2,470	\$1.64	\$3,880	\$2,832

Source: USDA-NASS, 2024 and Almond Board Public Releases, 2024.

## B. Almond Shipments

Total shipments in the 2023/24 season reached 2.470 billion pounds, with the U.S. consuming 515 million pounds, accounting for 21% of overall shipments (Figure 2). Exports made up 79% of total shipments, reaching more than 100 countries worldwide. The 2023/24 export shipments were the largest on record.

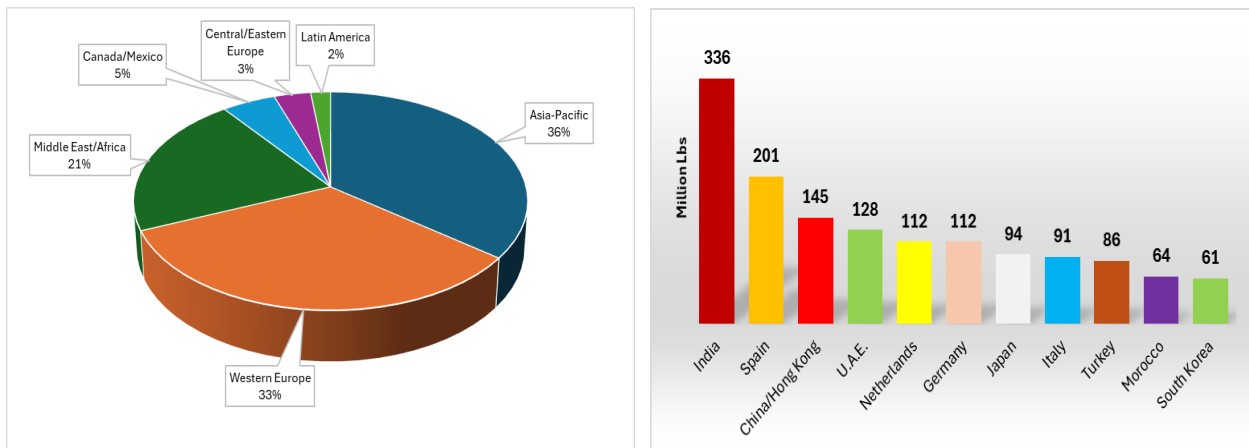


Source: USDA-NASS, 2024, USDA-FAS, 2024 and Almond Board Report, 2023.

Figure 2. Almond Shipments and Export Types (Shelled basis).

In the 2021/22 season, shelled almond exports decreased by 211 million pounds compared to the 2020/21 season. Manufactured almond exports remained nearly stable, decreasing by just 1% to 145 million pounds. In-shell almond exports also declined by just over 1%, dropping by 7 million pounds from the previous year.

In 2023, the top five export destinations for almonds—India, Spain, China/Hong Kong, the United Arab Emirates, and the Netherlands—made up around 47% of total export shipments from the United States. India maintained its position as the leading export destination, receiving 336 million pounds of almonds. This figure was nearly consistent with its strong performance in previous years, showing a 9% increase compared to the 2012 export quantity. Asia-Pacific, at 663 million pounds, remains the largest export region in 2023. Western Europe accounted for 33% of exports at 620 million pounds.

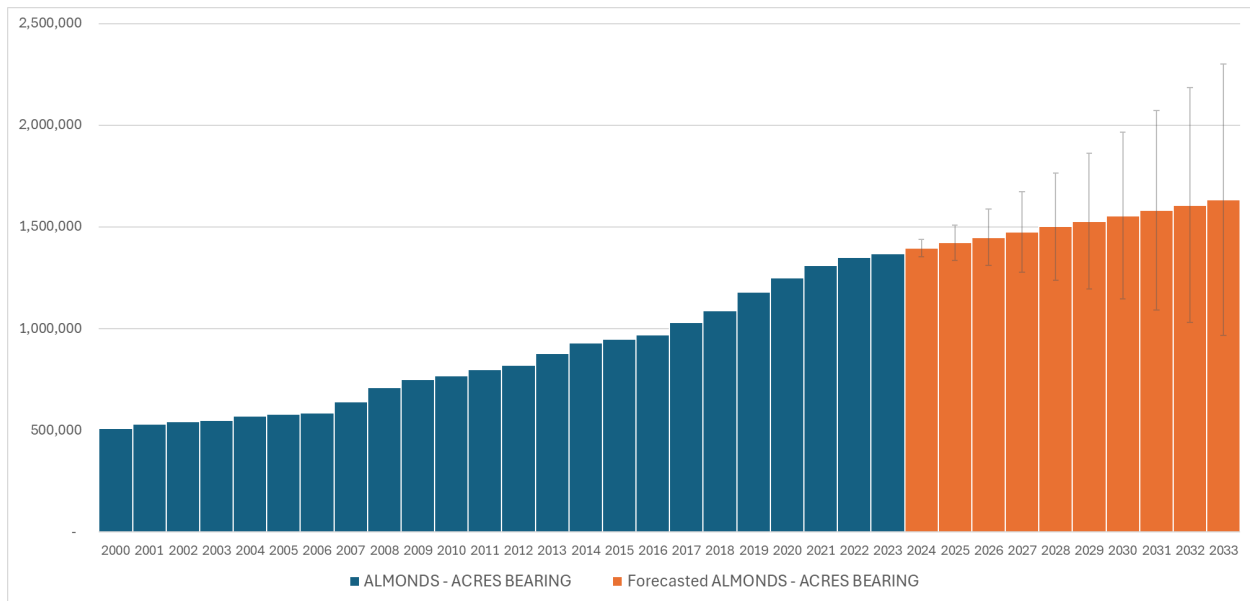


Source: USDA-FAS, 2024 and World Bank-WITS, 2024.

Figure 3. Top Ten Export Destinations and the Regional Exports (Shelled basis).

### C. California Almond Acreage and Prices - Historical and Forecast

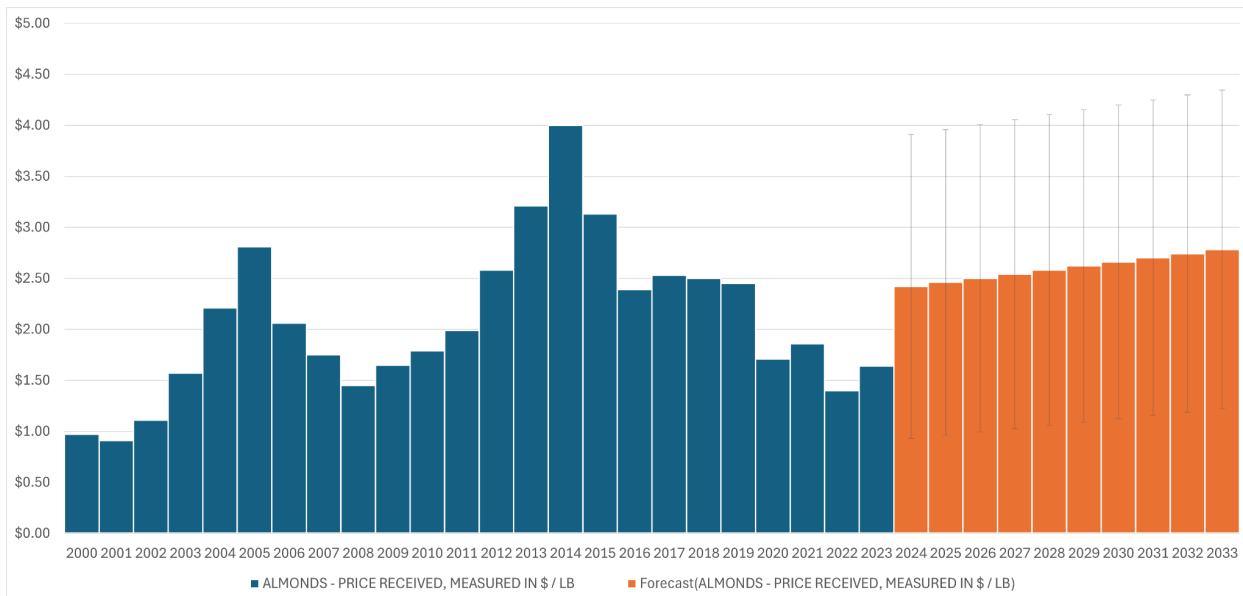
Figure 4 illustrates California's annual bearing almond acreage from 2000 to the present, with forecasts extending through 2033. The almond acreage has been consistently increasing over the past 20 years, growing from 0.5 million acres in 2000 to 1.37 million acres in 2023. The forecast predicts that this growth will continue in the near future, but there is a high possibility of it plateauing or slowly declining in the coming years. This estimation is based on the expanding confidence interval of the forecast over time.



Source: USDA-NASS, 2024 and Authors' forecast using Excel forecast function.

Figure 4. California Almond Acreage Bearing History and Forecast

Historical farm prices for almonds have been at their lowest levels since 2006 and have been declining since the record peak of \$4/lb in 2014. However, increasing demand for almonds and California's sustainable farming practices indicate an upward trend in forecasted prices. Our calculations suggest that almond prices will average over \$2.5/lb in the future. Nonetheless, factors such as environmental and labor regulations—specifically the Sustainable Groundwater Management Act (SGMA), immigration policies, minimum wage laws, and changing environmental conditions—could negatively impact price stability (Sunding and Roland-Holst, 2020; Martin, 2017; Richard, 2018).

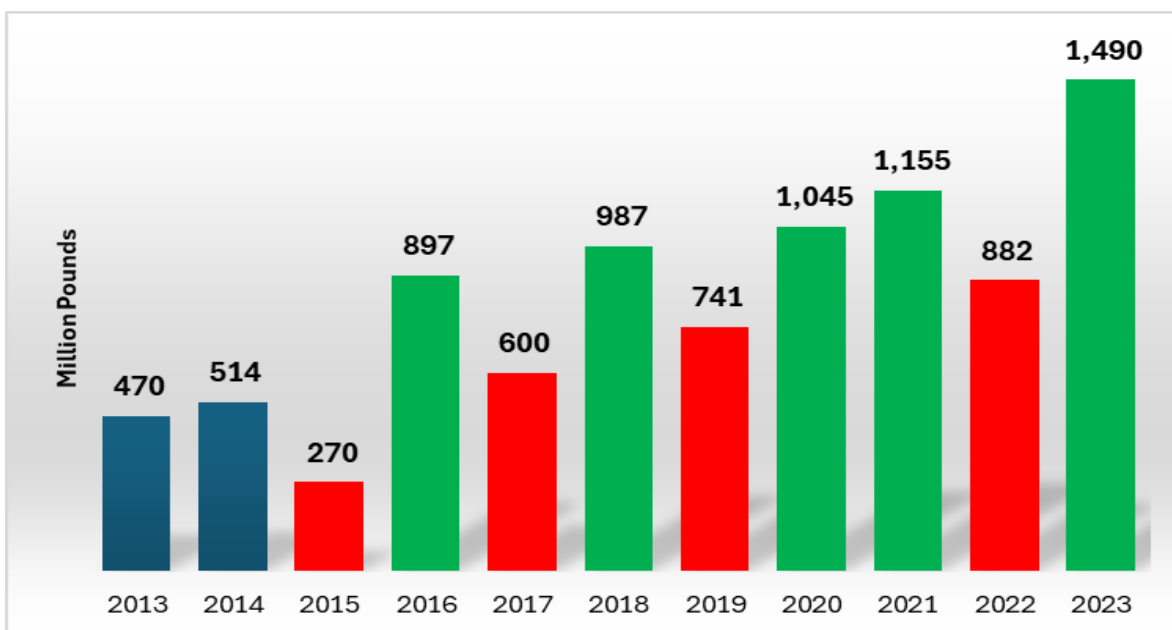


Source: USDA-NASS, 2024 and Authors' forecast using Excel forecast function.

Figure 5. California Almond Farm Prices History and Forecast

### III. California Pistachio Production

The 2023 production reports show that the cool spring and mild temperatures throughout the year created favorable conditions for pistachio cultivation. Larger nut sizes were seen, which is uncommon during an "on" year. Adequate moisture in the spring from winter rains and ample water availability during the year supported healthy growth. However, some growers experienced challenges due to spring flooding in the Tulare Lake basin, resulting in tree losses and debris accumulation from broken levees and overflowing rivers.



Source: CDFA, 2024

Figure 6. Pistachio Shipments from California (In-Shell Basis).



Nevertheless, the 2023 crop year production has reached a record 1.49 billion pounds (Figure 6). A large bearing yield of 3,220 lbs./acre also contributed to the record production weight in 2023.

Navel Orangeworm (NOW) remains a concern in pistachio, almond, and walnut orchards, and this year saw high NOW pressure in many almond orchards across the San Joaquin Valley. Lower almond returns led some growers to reduce cultural practices, contributing to higher NOW counts in almond orchards. Some almond loads experienced up to 50–60% NO damage. Despite this, pistachio orchards did not face unusually high damage. Insect damage stayed low throughout the pistachio harvest, thanks to better hull integrity and growers' adoption of proper winter orchard sanitation, timely crop protection material use, and mating disruption techniques such as puffers.

Growers reported higher percentages of open in-shell pistachios and fewer blanks. Golden Hills variety growers noted completing harvest with one shake rather than the usual two. Harvest of Golden Hills started in late August, about 8–10 days later than usual in 2023. Kerman variety harvest commenced in September and lasted through October.

### A. California Pistachio Acreage and Crop Value

Table 2 presents California's pistachio acreage, including both bearing and non-bearing acres, from 2012 to 2023. Crop values are reported as returns per pound, based on data from the USDA National Agricultural Statistics Service (USDA-NASS), and also expressed as returns per acre for growers.

Table 2. California Pistachio Acreage and Farm Value

Year	ACREAGE			YIELD		VALUE		
	BEARING	NON-BEARING	TOTAL	BEARING YIELD LB / ACRE	PRODUCTION MILLION LBS	FARM PRICE \$ / LB	FARM VALUE MILLION \$	VALUE PER ACRE
2012	182,000	62,308	244,308	3,030	551,000,000	\$2.61	\$1,438,110,000	\$7,902
2013	203,000	68,068	271,068	2,320	470,000,000	\$3.48	\$1,635,600,000	\$8,057
2014	221,000	75,940	296,940	2,330	514,000,000	\$3.57	\$1,834,980,000	\$8,303
2015	233,000	79,210	312,210	1,160	270,000,000	\$3.29	\$888,300,000	\$3,812
2016	239,000	78,210	317,210	3,750	896,500,000	\$1.68	\$1,506,120,000	\$6,302
2017	250,000	157,169	407,169	2,400	600,300,000	\$1.69	\$1,014,507,000	\$4,058
2018	264,000	151,683	415,683	3,739	987,000,000	\$2.65	\$2,615,550,000	\$9,907
2019	340,000	129,226	469,226	2,179	741,000,000	\$2.81	\$2,082,210,000	\$6,124
2020	372,000	114,121	486,121	2,809	1,045,000,000	\$2.51	\$2,622,950,000	\$7,051
2021	409,000	111,129	520,129	2,824	1,155,000,000	\$2.52	\$2,910,600,000	\$7,116
2022	428,000	127,716	555,716	2,061	882,000,000	\$2.11	\$1,861,020,000	\$4,348
2023	462,000	129,650	591,650	3,220	1,490,000,000	\$2.00	\$2,980,000,000	\$6,450

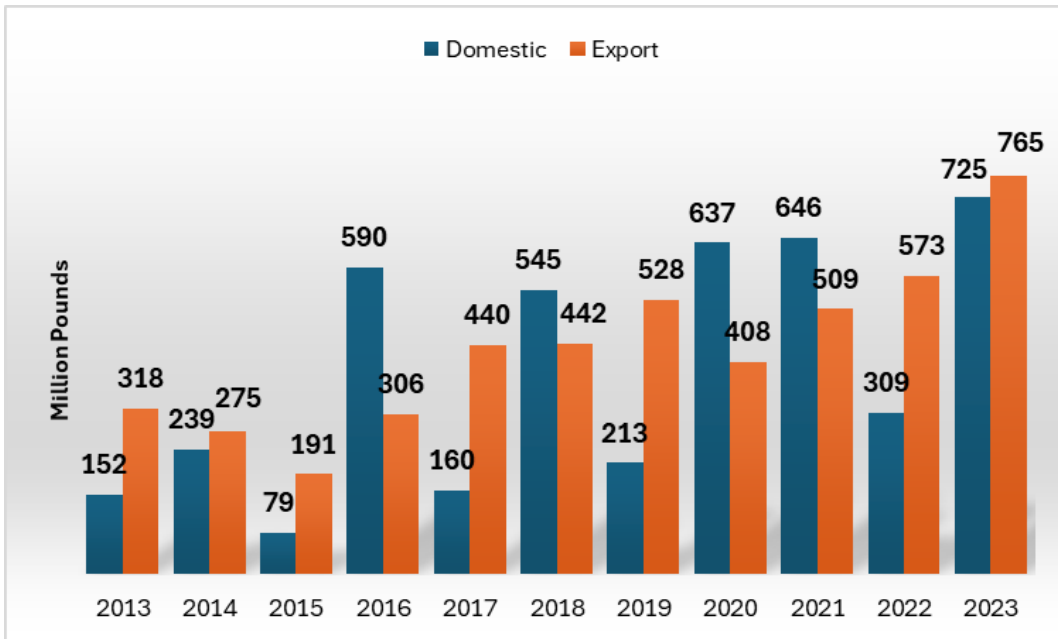
Source: USDA-NASS and American Pistachio Growers Public Releases, 2024

Pistachio farm values fluctuate due to the alternating cycles of "on" and "off" years and varying grower price payments. The USDA National Agricultural Statistics Service (USDA-NASS) reported that the 2023 farm gate crop value was almost \$3 billion. In terms of state production rankings, pistachios currently stand in the top ten largest commodities in California, though this ranking has varied from fourth to eighth over the last few years. Pistachios remain a top export from the state, consistently ranked as the third largest commodity exported from California, following dairy and almond products.

### B. Pistachio Shipments

Domestic and export shipments for the U.S. pistachio industry in 2023 totaled about 1.5 billion pounds. This marks a record of shipments and represents a 29% increase over the second-largest shipment in 2021.

During the crop year, domestic shipments reached 725 million pounds, marking another record compared to the 2021 shipment. Despite a decline in 2022, production increase in 2023 was reflected highly in the domestic shipment of pistachios.

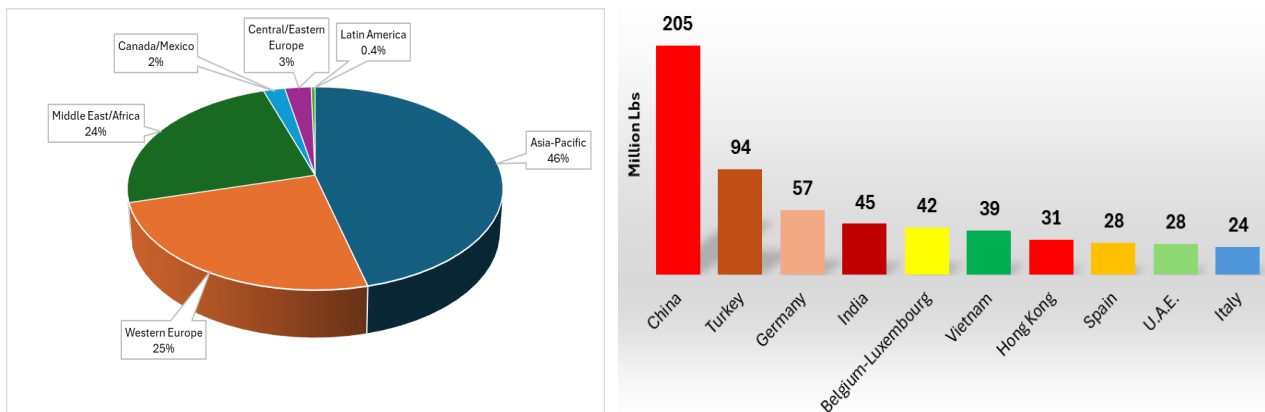


Source: USDA-NASS, 2024, USDA-FAS, 2024 and American Pistachio Growers Report, 2023

Figure 7. Pistachio Shipments Domestic versus Export.

Export shipments for the crop year totaled 765 million pounds, marking a 33.5% increase over the previous year. Shipments to the Western European countries experienced a slight decrease, from 196.2 million pounds to 188.5 million pounds, but the EU remained one of the top destinations for American-grown pistachios, while China/Hong Kong became the top destination in 2023. Shipments to China, including Hong Kong, increased from 184 million pounds to 236 million pounds, a 28% rise, though this figure is lower than the record 246 million pounds exported in the crop year 2018/2019 before the implementation of tariffs. There is potential for continued growth in this market.

India, which has been a focus of American Pistachio Growers' promotional and educational efforts, saw significant growth in shipments, rising from 27.9 million pounds to 45.1 million pounds, an increase of 61%. Shipments to the Middle East/Africa also showed a substantial gain, increasing to 185 million pounds in 2023.



Source: USDA-FAS, 2024 and World Bank-WITS, 2024

Figure 8. Top Ten Export Destinations and the Regional Exports

The impact of tariffs on shipments to China, which were imposed in 2018, remains uncertain.



Currently, tariffs stand at 50% on raw pistachios and either 15% or 30% on roasted pistachios. Nevertheless, shipments have stayed robust as importers can apply for a 5% tariff rate with the Central Government. This reduction is renewed annually, but its future availability and impact are unclear.

### **C. Pistachio World Production and Trade**

The United States and the Islamic Republic of Iran (IRI) are the world's largest producers of pistachios. In 2008, the U.S. surpassed Iran as the top producer and has maintained that position, except in 2015, when drought and a warm winter led to a smaller crop. Turkey and Syria are the third and fourth largest producers, respectively. Spain's recent and ongoing pistachio plantings could lead to substantial increases in production over the next decade, potentially making it the fourth-largest producer globally.

In May 2023, APG sent a small delegation to Spain to meet with growers and the European Pistachio Council. Spain's acreage is mostly rain-fed, with only 10% irrigated using modern techniques like double-line drip and UC1 rootstock with Golden Hills cultivar. Water application is limited to one acre foot or less per acre. Spain is expected to produce just over nine million pounds in 2023 and projects production of 20 million pounds by the end of the decade.

In Iran, ongoing drought is reportedly reducing production in the Kerman region, the country's main pistachio hub, causing 12,000 to 15,000 hectares to go out of production. Some growers have relocated to regions such as Saveh, Qazvin, and South Khorasan. Iran is expected to produce 200,000 metric tons in 2023, a significant increase from the 106,000 metric tons produced in 2021.

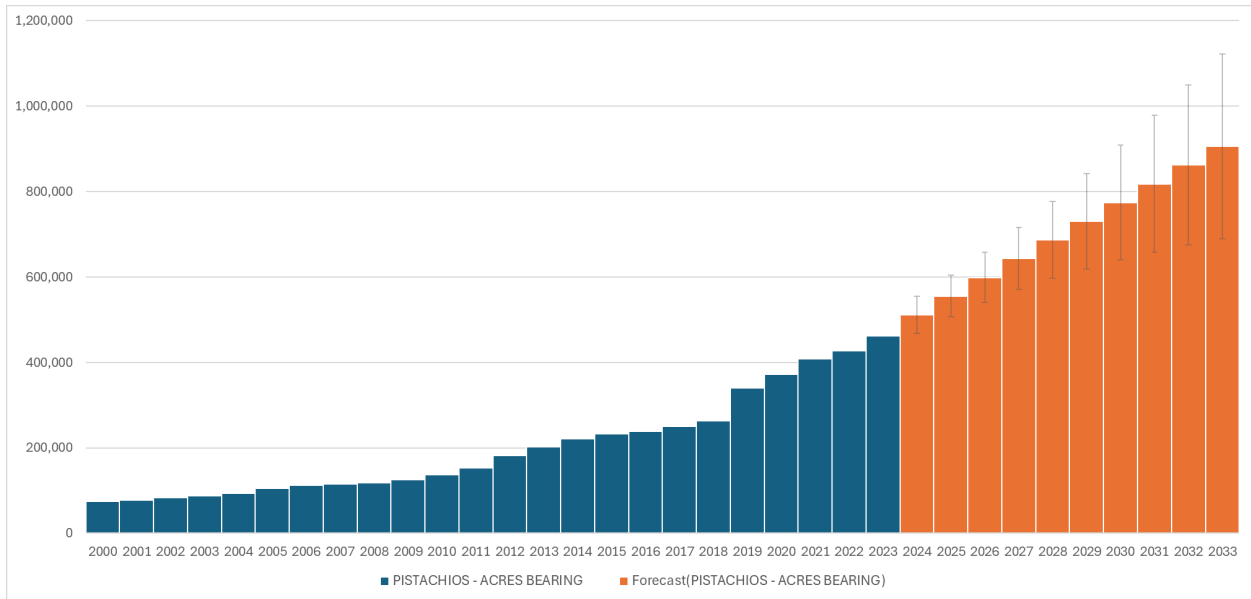
In Turkey, production is expected to reach 190,000 metric tons in 2023, slightly lower than the 200,000 metric tons produced in 2022. Turkey's pistachio production is primarily concentrated in the southeastern provinces of Gaziantep and Sanliurfa, which account for 80% of production. The Gaziantep (Antep) and Siirt varieties are unique to Turkey in terms of size and shape and make up the vast majority of production. While irrigated orchards have increased in recent years, only a small portion of total production is irrigated. Yields can vary significantly between 'on' and 'off' years, with 9 pounds per tree in 'on' years and around 4.5 pounds per tree in 'off' years.

### **D. California Pistachio Acreage and Prices - Historical and Forecast**

The following chart demonstrates California's annual pistachio-bearing acreage from 2000 to 2023 (Figure 9). The chart also includes a ten-year forecast based on historical acreage trends. Similar to almonds, pistachio acreage has seen a significant increase over the past 20 years, reaching 462 thousand acres in 2023, up from just 75 thousand acres in 2000. Our projections suggest that this trend will continue, potentially surpassing 600 thousand acres by 2029, based on the lower 95% confidence interval boundary. The forecast further indicates that the acreage could exceed 800 thousand acres by 2031.

In 2023, the American Pistachio Growers (APG) also commissioned an updated study to forecast pistachio acreage and production over the next several years. Their forecast used current data as 453,750 bearing acres and an additional 129,650 nonbearing acres in California, accounting for 99% of U.S. pistachio production and they included an additional 8,000 to 10,000 acres of pistachios located in Arizona and New Mexico.

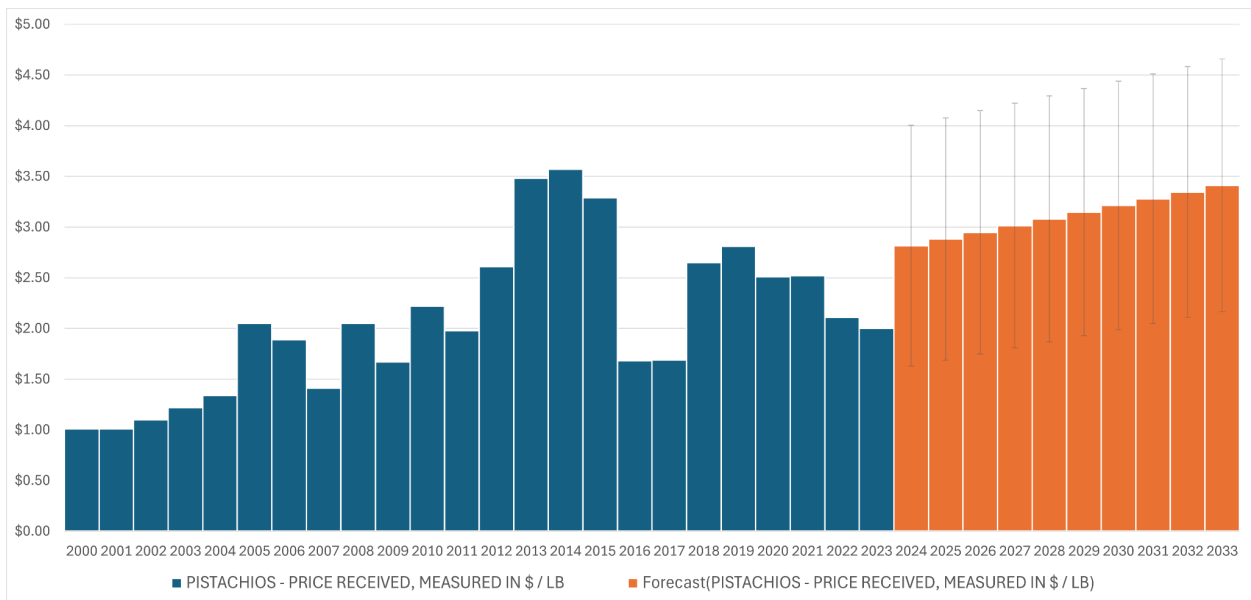
Their projections show an increase in the number of bearing acres from 453,750 acres to 668,850 acres by 2031, representing an annual growth rate of 5.1%. Total acres are expected to increase from 583,400 acres in 2023 to nearly 811,300 acres by 2031, reflecting a 4.3% annual growth rate. These results align greatly with our acreage forecasts.



Source: USDA-NASS, 2024 and Authors' forecast using Excel forecast function.

Figure 9. California Pistachio Acreage Bearing History and Forecast

The chart in Figure 10 illustrates California's annual pistachio prices from 2000 to the present, with forecasts extending through 2033. Similar to almond prices, pistachio farm prices peaked in 2014 at \$3.57/lb and have shown a declining trend since then. USDA-NASS (2024) estimates the 2023 farm price at \$2/lb on average. However, our price projections indicate a robust increasing trend over the next ten years. Although prices may fluctuate yearly due to the alternate production cycle of pistachios and other factors such as legislation and climate, we expect prices to approach \$3.5/lb by 2033.



Source: USDA-NASS, 2024 and Authors' forecast using Excel forecast function.

Figure 10. California Pistachio Farm Prices History and Forecast

## **E. Pistachio Marketing**

Like other tree nut industries that highlight health and nutritional benefits, pistachios emphasize their unique advantages—pistachios are the lowest-fat nut and contain a serving size of one ounce that includes protein (6g per serving), potassium (290 mg per serving), and fiber (3g per serving). Additionally, a serving contains 49 pistachios, more than any other tree nut, with only 160 calories. Pistachios also provide several antioxidants that help protect against oxidative stress, contributing to the prevention of many chronic diseases. The pistachio industry continues to fund promising nutrition research on the prevention of heart disease, diabetes, cardiovascular diseases, obesity, and cancer (Matoian, 2023).

In 2020, American Pistachio Growers, with Dr. Mehmet Oz's support, announced a new study finding that pistachios are a complete protein, containing the nine essential amino acids our bodies need but cannot produce naturally. Other sources of complete protein include meat, eggs, seafood, and dairy. This research provides the pistachio industry with an additional health attribute to promote to consumers.

In 2022, APG presented findings from a Cornell University study published in the journal *Nutrients*, showing that pistachios have a very high antioxidant capacity, ranking among the highest when compared to other antioxidant-rich foods such as blueberries, cherries, beets, pomegranates, and red wine. Researchers used two methods of measuring antioxidants: ORAC (Oxygen Radical Absorbance Capacity), the USDA-established standard, and CAA (Cellular Antioxidant Activity). Pistachios scored highly in both categories. Health professionals recommend antioxidants from food sources to help protect cells from damage and combat diseases and premature aging (Matoian, 2023).

Pistachios have gained significant exposure through branded company campaigns and American Pistachio Growers' "The Power of Pistachios" campaign. All public relations and marketing campaigns, whether generic or brand-specific, help introduce and familiarize consumers with pistachios. These campaigns strengthen consumer education on pistachios, encouraging their inclusion in a healthy, flavorful diet. Continued marketing, PR, and nutritional efforts will keep consumers focused on the health and nutritional value of pistachios, ensuring consistent demand for American-grown pistachios.

## **IV. Conclusion**

In summary, California's almond and pistachio industries are central to global nut production, and their continued success is a testament to the state's commitment to innovation and sustainability. The state's unique Mediterranean climate, paired with the dedication of local farmers, drives advancements in farming practices such as micro-irrigation and groundwater recharge to ensure water sustainability. Despite challenges from climate and pests, the industries remain resilient and proactive in adopting effective management strategies. California's leadership in almond and pistachio production is further bolstered by ongoing research and marketing initiatives that enhance the global perception of these nuts' health benefits and nutritional value. The growth in exports, particularly to emerging markets like India and the Middle East, showcases the potential for continued expansion. While tariff challenges persist in some markets, the industries' adaptability and strategic approaches position them well for future growth. The almond and pistachio sectors in California stand as exemplars of sustainable agriculture and robust international trade, demonstrating how an industry can thrive by balancing economic success with environmental stewardship. Their ongoing commitment to sustainable practices ensures their pivotal role in the global market for years to come. In the future, we will continue to assess the impact of precision agriculture on the almond and pistachio industries.

## Acknowledgments

We would like to acknowledge the Almond Board of California and American Pistachio Growers for helping us understand the details of the industries and some statistical information that was provided online and at Fresno State's Annual Agribusiness Management Conference. We would also like special thanks to the Economic Development Administration (EDA) Project Grant 077907908, Fresno-Merced Future of Food Innovation (F3) Coalition.

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