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Alfalfa Export and Water Use Estimates for Individual States

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Abstract

Alfalfa hay is an important crop for the U.S., comprising 15.46 million acres on average over the last three years (2020-2022). In 2019, the farm value of alfalfa slightly exceeded wheat to be the third most valuable crop in the U.S., behind corn and soybeans. Alfalfa is crucial for the dairy industry, feedlot sector, equine industries, and agricultural exports. Alfalfa exports have been criticized as their source can be from water-scarce states. However, state-level export data are not readily available. Thus, we provide estimates of state-level alfalfa exports using port data (1994-2001) and Forage Products data (2002-2022) from U.S. trade online to help describe the amount of alfalfa that is being exported at the state level. We also provide estimates of the amount of water utilized by alfalfa exports for the seven exporting states using a range of water use estimates from various sources and USDA/NASS data.

Introduction

Over the past two decades, U.S. hay and forage product exports have increased remarkably, making the U.S. the lead exporter of forage products worldwide. U.S. alfalfa exports have consistently increased since 2002, increasing from 0.9 million metric tons (MT) in 2002 to 2.8 million MT in 2022, a 3-fold increase over 20 years. In addition, most of these exports originate from the seven western states of Arizona, California, Idaho, Nevada, Oregon, Utah, and Washington (Matthews and Summer, 2019; Putnam et al., 2013 and 2015). We estimate, on average, more than 99% originated from these seven states over the last five years (2018-2022). Top destinations for exports are China, Japan, Korea, Saudi Arabia, Taiwan, and the United Arab Emirates. The growth in alfalfa demand for these countries is mostly driven by an increase in demand for milk and meat products in Asia and restrictions on forage crop production in Middle Eastern countries (Matthews and Summer, 2019; Putman et al., 2018).

Alfalfa is often thought of as an inefficient crop for converting water to dry matter, but alfalfa can be more efficient in water use compared to many other crops due to the entire plant being marketable (Yost et al., 2020; Putnam et al., 2001). Due to water scarcity in these alfalfa exporting states, exports to foreign countries have been criticized as the equivalent of having water exported to those countries. Indeed, existing water rights do not allow for any market transfers of water to a foreign country, yet agricultural products which utilize irrigation water can readily move across foreign borders. How much water is being shipped from these states? The answer raises the need for

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state-level alfalfa hay export data. These data are not readily available due to the lack of state-level data on alfalfa quantities exported.

We first provide an overview of U.S. alfalfa's top export destinations. Then we estimate state-level alfalfa hay exports of these seven western states using port data (1994-2001) and Forage Products data (2002-2022) from U.S. trade online to help describe the amount of alfalfa exported at the state level.

Major U.S. Alfalfa Exports Destinations and Trends

As described in Figure 1, U.S. alfalfa exports have grown remarkably over the last 13 years, increasing from 1.7 million metric tons in 2009 to 3.2 million metric tons in 2022, an 88% increase. U.S. alfalfa is attractive because of its high quality and the highly competitive return freight costs or "empty containers" from Western U.S. ports to East Asia (National Alfalfa and Forage Alliance, 2014). China's alfalfa imports from the U.S. went from 82.7 thousand metric tons in 2009 to 1.8 million metric tons in 2022.

The impressive increase in China's alfalfa imports from the U.S. is mainly due to structural changes in its dairy industry, moving from small dairy farms to modern, large-sized dairies. Small dairies decreased from 2.37 million in 2008 to about 1.5 million in 2014 while large-sized dairies increased from 374 in 2002 to 3,585 in 2012. This shift represents nearly a 10-fold increase over just 10 years (Wang, Hansen, and Xu, 2016). In addition to the demand growth of more modern, large-sized dairies that exclusively utilize non-pasture nutrients, China has been unable to substantially grow its domestic production of high quality alfalfa to keep up with its consumer demand for dairy products.

Due to water policy conservation, in 2006, the United Arab Emirates (UAE) implemented a policy which banned the production of alfalfa in their country (Akhidenor and Taha,2012). This led the government to turn to the U.S. to fulfill its domestic alfalfa market needs and compete with other importers of U.S. alfalfa. The United Arab Emirates (UAE) became the second largest destination from 2009 to 2011. From 2008 to 2019, UAE's import volumes increased from 103 to 495 thousand MT, representing nearly a 5-fold increase. UAE's imports were largest in 2012 (598 thousand MT) and 2013 (662 thousand MT), accounting for 34% of total U.S. exports during those two years. However, starting in 2014, their import volumes have steadily declined.

In 2016, Saudi Arabia started a water conservation policy on forage production due to the country's groundwater depletion, and the phase out of green fodder cultivation became effective in 2019 (FAO, 2018). This led to a big jump in their alfalfa imports from the U.S. (267% increase), going from 75 thousand MT in 2015 to 275 thousand MT in 2017, a nearly 4-fold increase in just one year. Since 2017, Saudi Arabia has been the third top country importer of U.S. alfalfa, with a yearly average of 340 thousand MT imported between 2018 and 2022, ahead of South Korea, Taiwan, and the UAE.

The shares of U.S. alfalfa exports by volume have shifted drastically since 1994, especially between China and Japan, the two top destinations. As shown in Figure 1, Japan was the largest importer of U.S. alfalfa from 1994-2012. During this period, Japan's percentage share decreased substantially, going from 89% in 1994 to 26% in 2012. In 2009, Japan's share of total imports (44%) was almost 10-fold that of China's share (5%). But by 2015, China's share (45%) grew to nearly double that of Japan's share (24%). Due to the trade war between the U.S. and China, China's share decreased in 2018 (34%) and 2019 (32%). Still, China kept its position as the top U.S. importer of

alfalfa, unlike some predictions that expected Japan to regain its position as the lead importing country in 2019 (Matthews and Summer, 2019). In 2022 China's share was three times more than Japan's share, the second largest U.S. alfalfa importer.

Estimated Exports by State

Before 2002, state-level alfalfa hay export data are not available. However, forage products or Nesoi (HS code: 14910 and includes hay, clover, vetches, etc.) from 2002 to the present by state are available and provided by the U.S. Census Bureau (USITC, 2022, Figure 2). In addition, U.S. monthly alfalfa and all forage product export values are highly correlated (0.97) and have very similar trends as shown in Figures 2 and 3. More formally, to obtain state-level alfalfa exports from state-level forage and national port data, we use equation (1) for years between 1994 and 2001 as follows:

$$State_i(Alfalfa\ Export) = State_i(total\ alfalfa\ domestic\ exports\ from\ ports) \quad (1)$$

For years of 2002 and later, we use the ratio of all states' forage product exports (c) and alfalfa port exports (USITC, 2022) as a weight, which is then applied to individual monthly state forage product values to estimate state-level alfalfa export values as:

$$State_i(Alfalfa\ Export) = \frac{Total\ U.S.\ \ port\ level\ alfalfa\ Exports}{Total\ forage\ product\ exports\ from\ all\ states}\ \ State_i(forage\ product\ exports) \quad (2)$$

Figure 4 shows how our monthly state-level estimates compare with national FAS port data and how the total volume of alfalfa exports has been steadily increasing for the seven western states. These states also account for virtually all the alfalfa exported from the U.S. Total alfalfa export tonnage incurred an almost 10-fold increase from 1994 to 2022 (from 300 thousand to 3 million MT, see Figure 5). Alfalfa exports have consistently increased since 2002 at an annualized rate of 16 percent. California and Washington are the two top exporting states. Washington was the top alfalfa exporter from 1994 to 1999 and 2004 to 2009 (Table 1). But California has been the top exporter since 2012 (Table 1), with an average of 232 thousand MT and ahead of Washington for the last 10 years. More "empty containers" in Southern California have provided somewhat cheaper freight rates for California than Washington in the last decade.

State Alfalfa Production and Export Trends

While exports have been increasing, these seven western states have decreased their production of alfalfa during the last two decades (Figure 6). Thus, the percentage of alfalfa production going for exports has steadily increased, especially since 2002. Washington currently has the highest percentage of their alfalfa production going for exports, followed by Oregon and California. Idaho, the second largest producer of alfalfa, exports a small percentage since it is further from the ports and has a large dairy industry. Since 1994, the highest percentage of Idaho's alfalfa production exported has been 3% (2020). Oregon's alfalfa exports have also been steadily increasing and reached 17% in 2009 and 33% in 2022. This increase shows roughly a 2-fold increase over the last 14 years, with an average of 27% of their production exported between 2016 and 2022. Although alfalfa production in California has been declining steeply since 2002, going from more than 7 million MT in 2002 to around 3 million in

2022 (Figure 6, Table 1), their annual percentage of alfalfa production exported has increased from 6% to 38% since 2002 (Figure 7). The decline in alfalfa hay production in California can be attributed to several factors that have impacted the agricultural landscape in the region. These factors include water scarcity, land use changes, and competition from alternative crops (Cantor et al., 2022; Gebremichael et al., 2021; Johnson and Cody, 2015). Farmers have switched to alternative crops that are more profitable and often require less water than alfalfa.

California farmers have been shifting their focus to crops such as almonds and pistachios, which offer higher profitability (Gebremichael et al., 2021; Johnson and Cody, 2015). USDA/NASS (2022) shows a substantial increase in harvested acres for almonds and pistachios between 1996 and 2022. In contrast, there was a significant decline in harvested acreage for field crops like alfalfa. Almond acreage has increased more than 3-fold, rising from 428,000 acres in 1996 to 1.5 million acres in 2022. Similarly, pistachio acreage has increased more than 6-fold, growing from 64,300 acres to 428,000 acres over this same period. In contrast, alfalfa acres harvested have declined by over 50%, dropping from 940,000 acres in 1996 to 450,000 acres in 2022. This shift towards cultivating more permanent tree nut crops appears to be primarily driven by market demand (Gebremichael et al., 2021).

Between 1994 and 2001, total alfalfa production from the seven states has ranged between 17 and 19 million MT with a yearly average of 18.5 million acres over the 8-year period (Figure 7 and Table 2). From 2002 to present, total alfalfa production has been declining, going from 20 million MT in 2002 to 14.8 million MT in 2022. However, the total estimated alfalfa production exported from the seven western states has been going up consistently from 302 thousand MT in 1994 to nearly 3 million MT in 2022. The percentage of total production exported from the seven western states went from 2% in 1994 to 20% in 2022, an 18 percentage point increase. Using our estimated state alfalfa export volumes, we find that the seven western states collectively exported 20% of their production in 2021 (Figure 7, Table 2). This percentage is consistent with that reported by Rankin (2022).

Water Utilized by Alfalfa Exports

To determine the amount of water utilized in alfalfa exports from each state, we utilize numerous cost of production studies for the seven western states and the USDA/NASS Census of Agriculture 2018 Irrigation and Water Management Survey to come up with a range of water used to produce an acre of alfalfa in each state (USDA/NASS, 2019). We determine the acres exported and water use by dividing our state-level exports with USDA/NASS state yield averages. We also show a range for the total irrigation water utilized for alfalfa exports by using the 2018 Irrigation and Water Management Survey estimates of irrigated acres and water use for all crops by state, and assuming that all alfalfa exported is grown under irrigation.

Because water use estimates vary by location, weather conditions vary, and irrigation technology is steadily shifting to more efficient delivery systems through sprinkler irrigation, laser leveling, and other technologies, a low and high range is provided for the water used to grow an acre of alfalfa (Table 3). Water needed to grow an acre of alfalfa ranges from a high of 7.5 acre-feet/acre in Arizona to a low of 2.0 acre-feet/acre in Idaho or Washington. However, Arizona, with its longer growing season, had a 2018-22 average yield of 8.3 tons/acre versus only 4.3 and 4.7 tons/acre for Idaho and Washington.

Consistent with export quantities, the coastal states of California, Washington, and Oregon utilize the most water to produce their alfalfa exports. Although California is estimated to utilize the most water to produce its alfalfa exports, it uses a smaller percentage of its irrigation water than relatively small exporting states like Utah and Arizona. We estimate that California uses a lower percentage of its total irrigation water for alfalfa exports than Washington, Oregon, Utah, and Arizona. California utilizes such a large quantity of water for all its crops and alfalfa is a smaller percentage of California's crop portfolio than the aforementioned states. Alfalfa accounts for about only 5% of California's irrigated acreage whereas it accounts for about 35% of Utah's and 24% of Arizona's irrigated acreage (2018-22 average).

For the seven western states, alfalfa exports collectively utilize around 1.4 to 2.2 million acre-feet of water or 3-5% of the irrigation water applied in these states. The largest percentage estimate is for the state of Washington (15%), which also exported over 60% of its alfalfa production in 2022. Thus, alfalfa exports do not currently account for an extraordinarily large quantity of irrigation water utilized from these seven western states. If alfalfa exports continue to grow at the pace they have over the last decade, political pressure will likely increase to reduce the volume of alfalfa exports, particularly during periods of drought.

Summary and Conclusions

Alfalfa hay is a vital input for livestock and dairy operations and an important cash crop which contributes to the economy of western states and all the stakeholders involved in alfalfa exports. Our state-level estimates show that the seven western states account for virtually all alfalfa exports from the U.S. and that alfalfa exports have experienced remarkable growth since 2007. Yet alfalfa production has declined quite dramatically for these seven states while the percentage of production going for export has climbed dramatically, especially for the coastal states of Washington, Oregon, and California. Although California uses more water than the other seven states to produce its relatively large tonnage of alfalfa exports, California uses a rather small percentage (2-4%) of its total irrigation water to produce this alfalfa.

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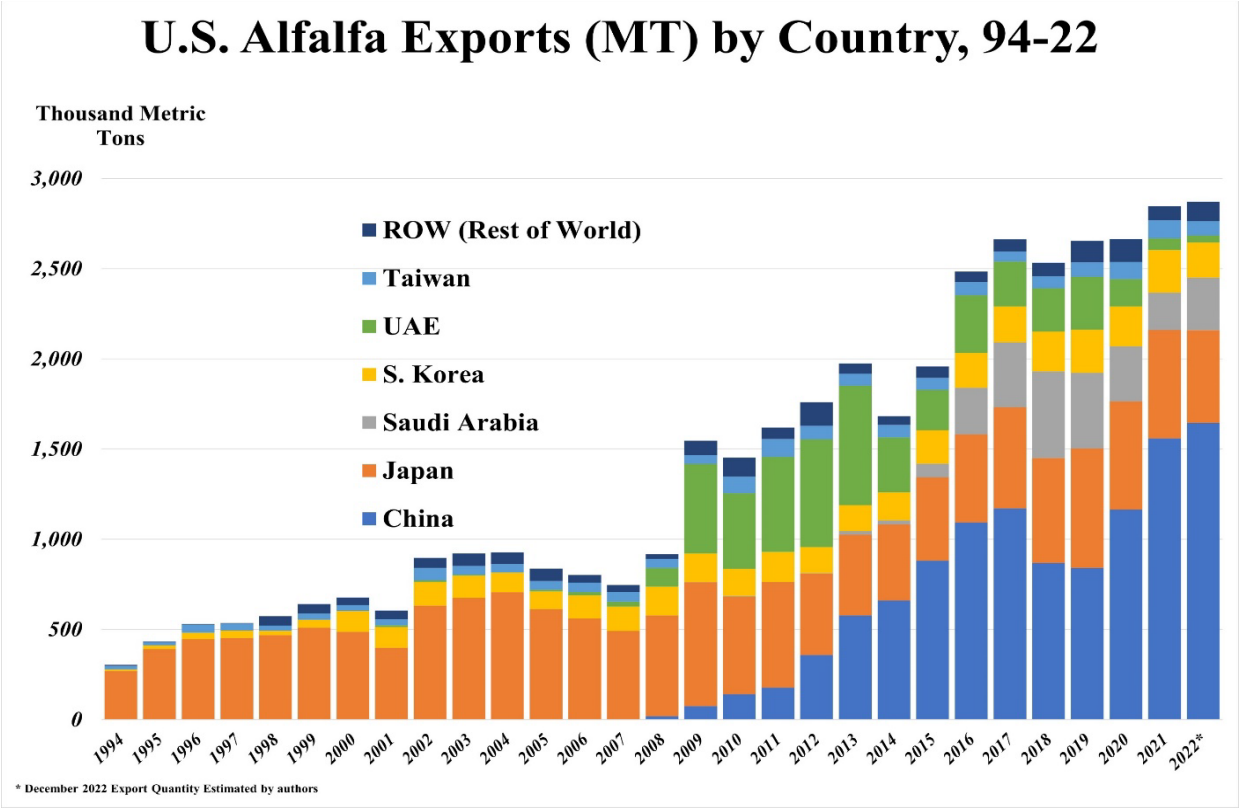

Figure 1: U.S. Alfalfa Export Quantities by Top Country Destinations

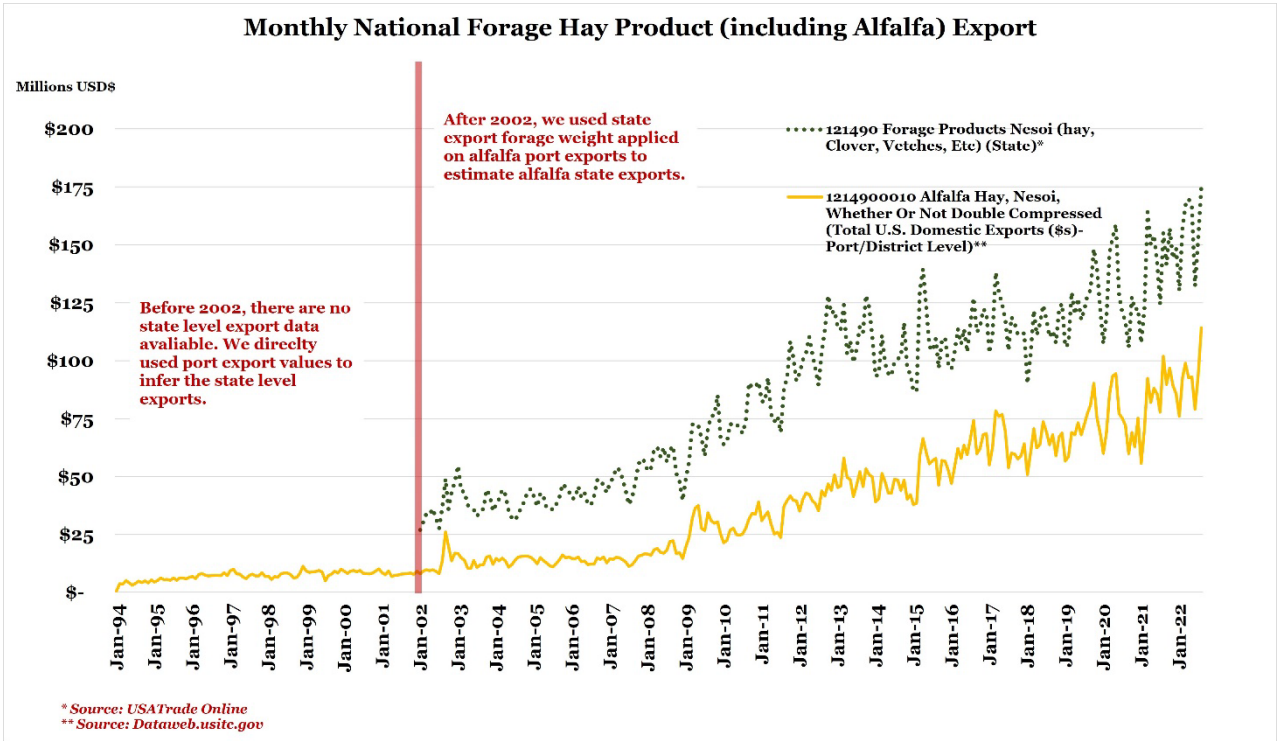

Figure 2: Monthly U.S. Forage Products (including Alfalfa) Export Values

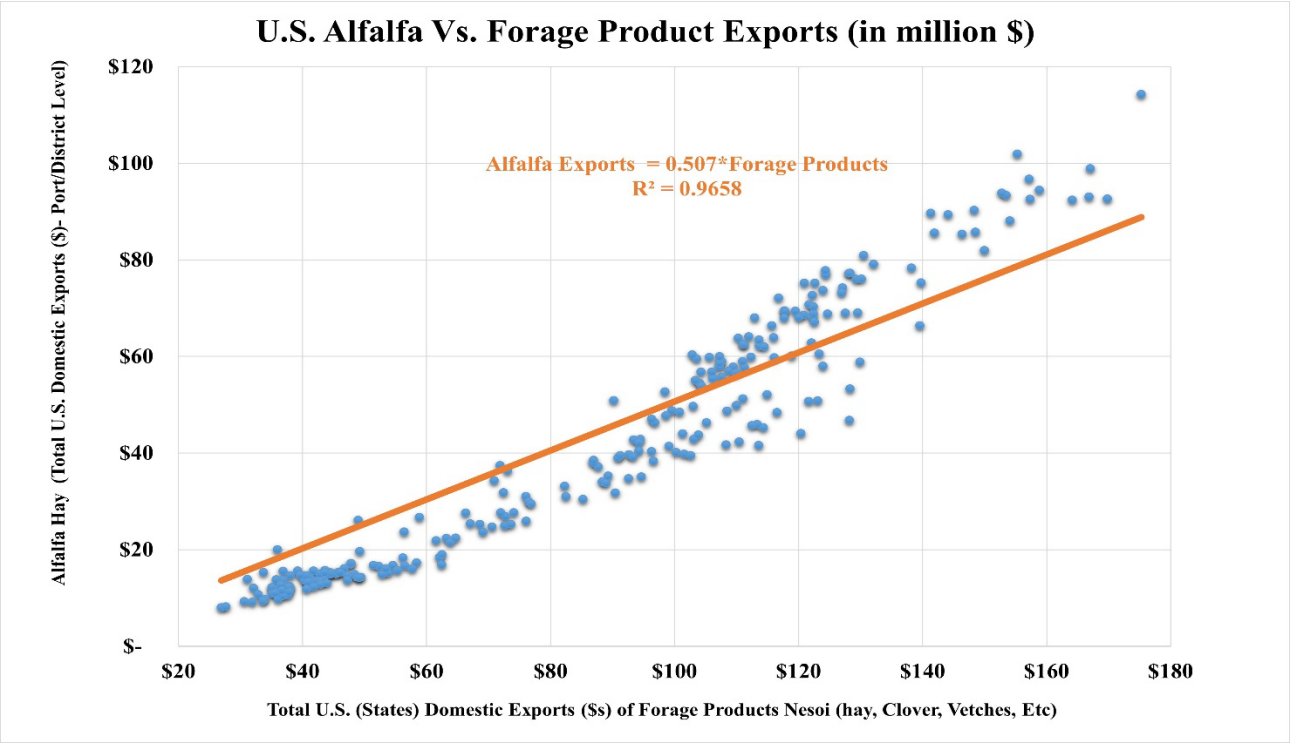

Figure 3: Relationship of U.S. Alfalfa Exports ($) to All States to Forage Product Exports ($)

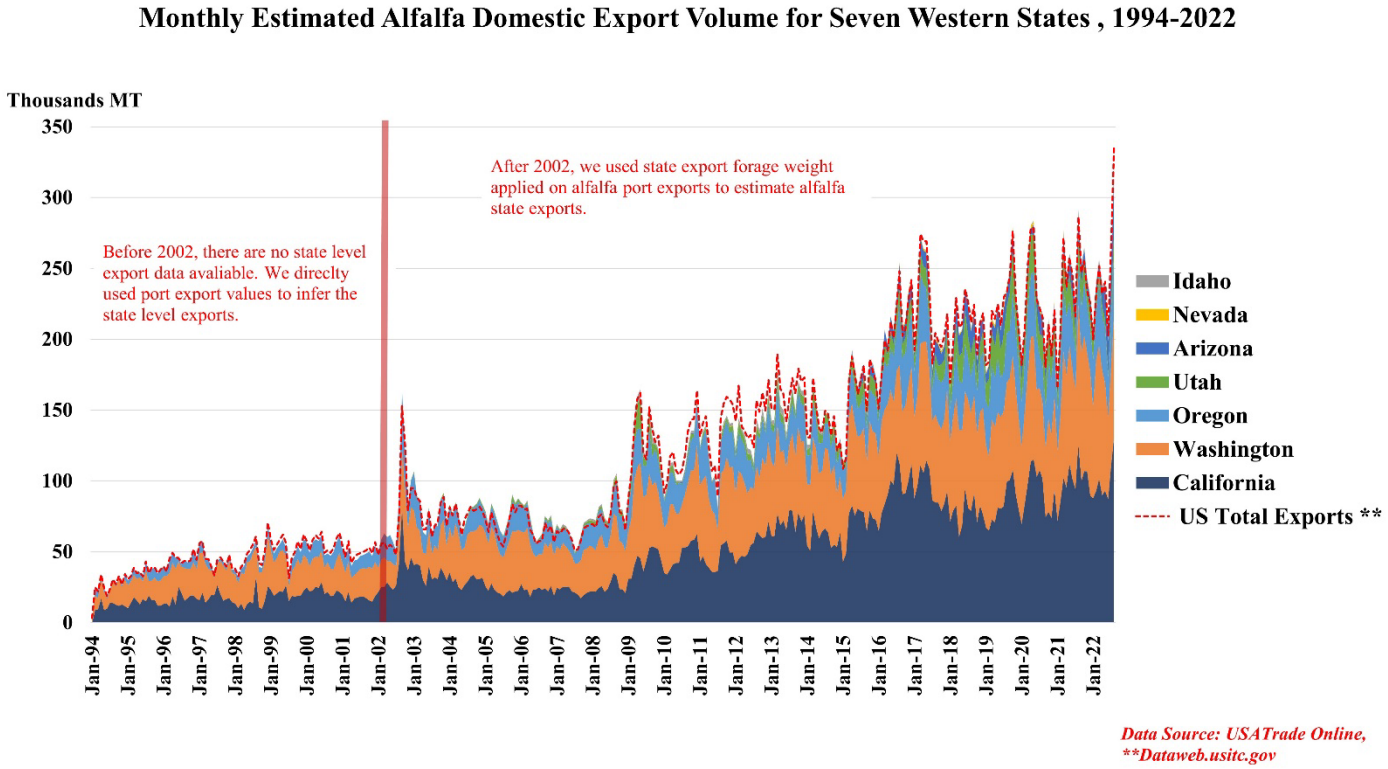

Figure 4: Monthly Estimated Alfalfa Domestic Export Volume for U.S. and Seven Western States from 1994 to 2022

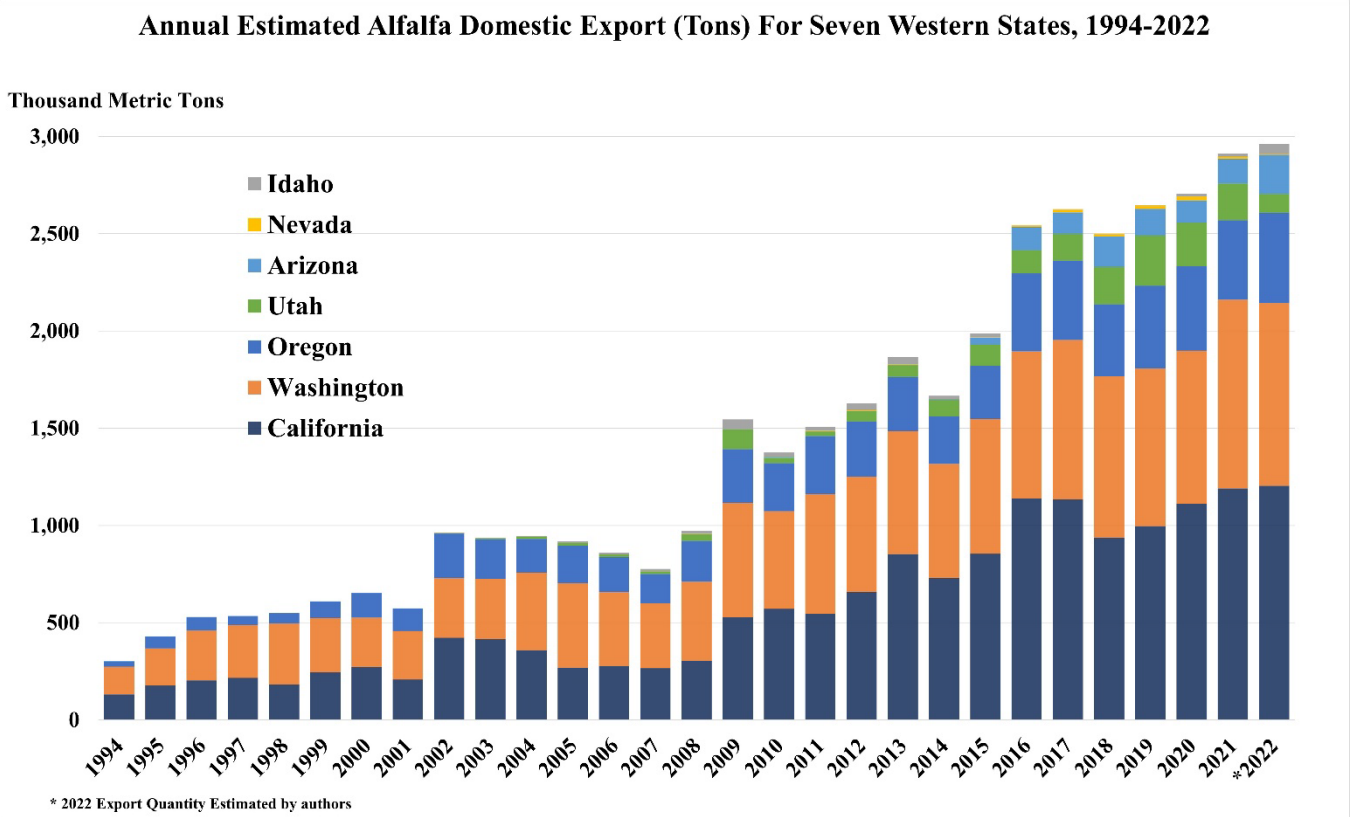

Figure 5: Estimated Total Alfalfa Domestic Exports Volume by State for the Seven Western States from 1994 to 2022

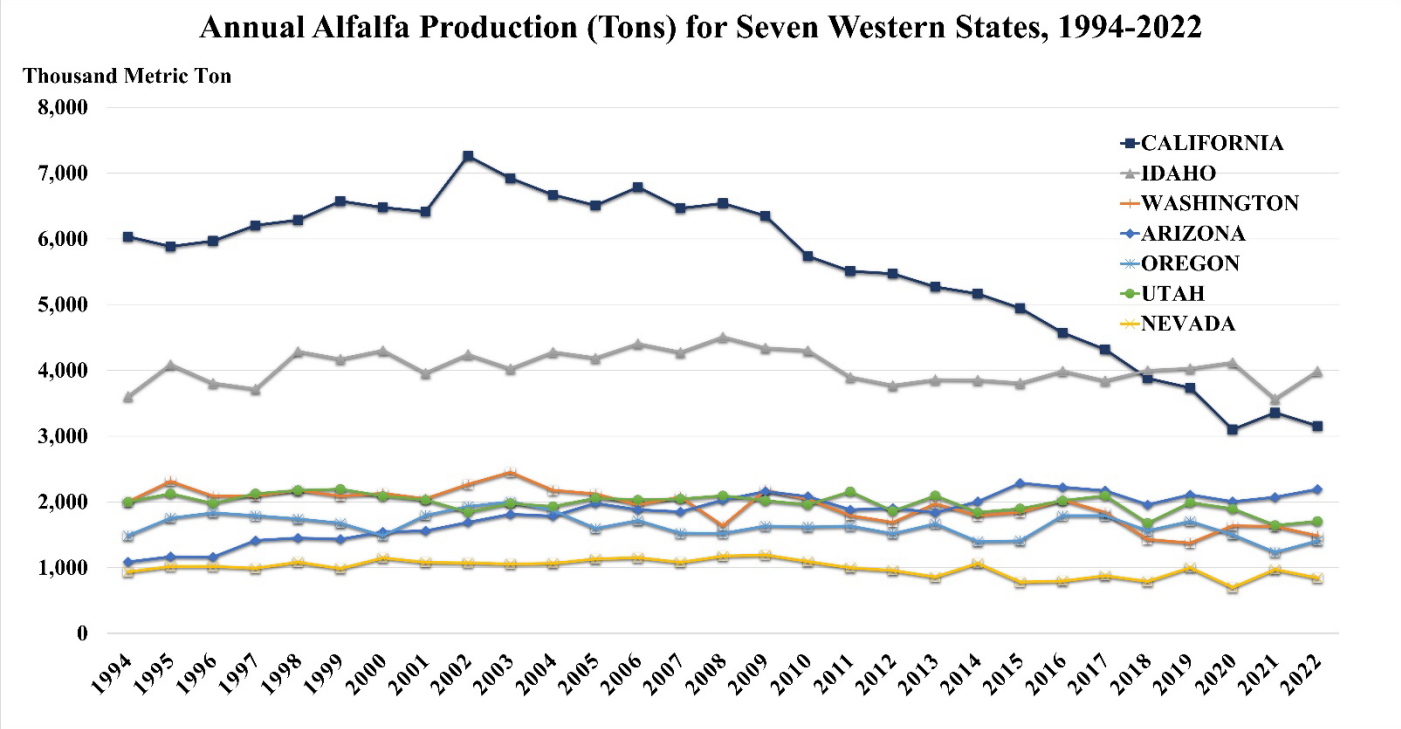

Figure 6: Annual Alfalfa Hay Production (Metric Tons) by State for Seven Western States

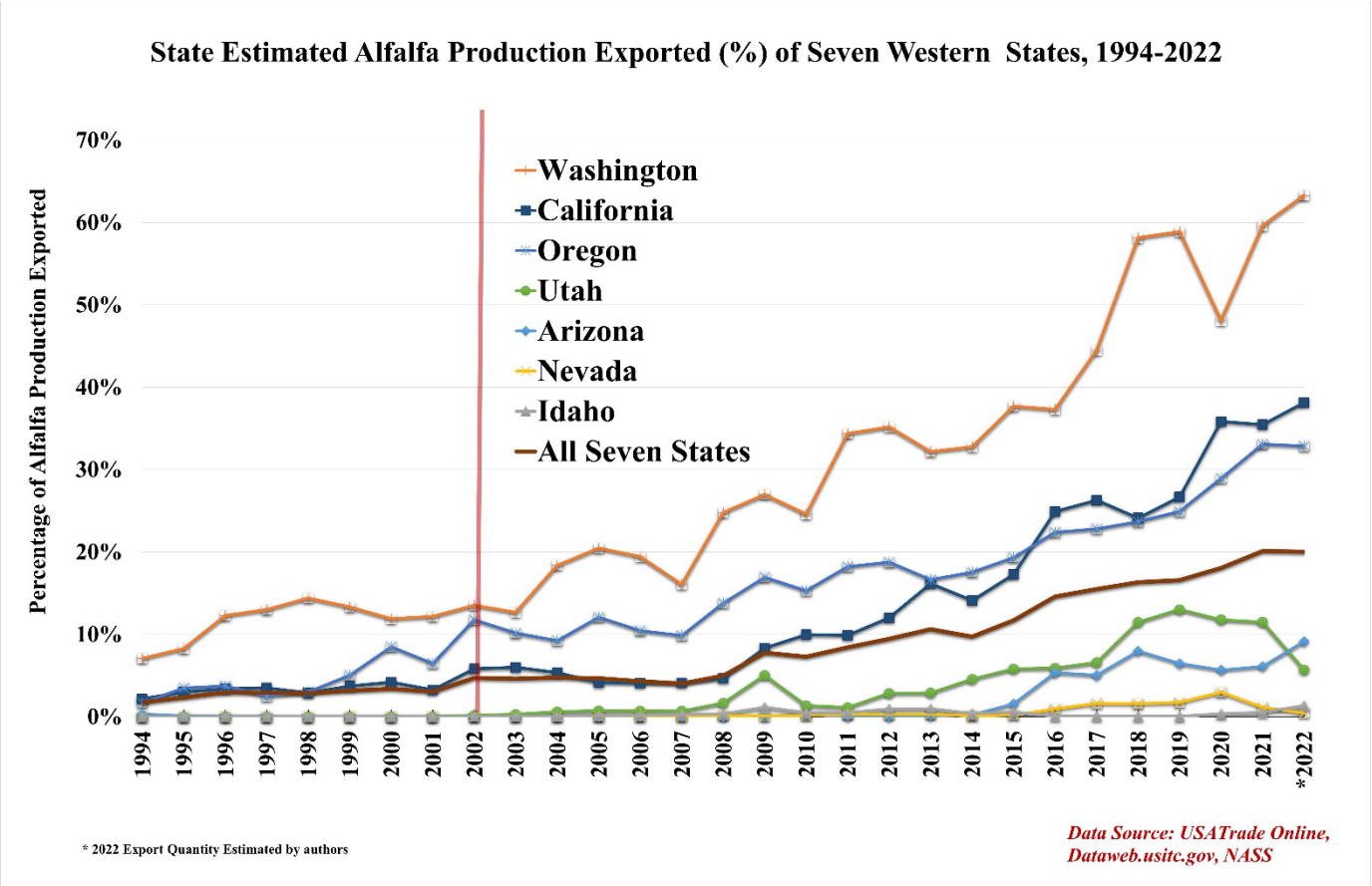

Figure 7: State Estimated Alfalfa Production Exported (%) of Seven Western States, 1994-2022

Table 1: Total Annual Alfalfa Production and Domestic Export Quantities (in thousand Metric tons) for Seven Selected Western States

*Export quantities for September to December 2022 are estimated by the authors using US export data.

Year	ARIZONA (1,000 MT)		CALIFORNIA (1,000 MT)		IDAHO (1,000 MT)		NEVADA (1,000 MT)		OREGON (1,000 MT)		UTAH (1,000 MT)		WASHINGTON (1,000 MT)	
	Production	Export	Production	Export	Production	Export	Production	Export	Production	Export	Production	Export	Production	Export
1994	1,088.6	3.4	6,032.8	131.6	3,608.8	0.0	936.2	0.0	1,487.8	25.3	2,000.3	0.0	2,004.0	142.2
1995	1,167.5	0.9	5,884.0	177.5	4,091.4	0.0	1,020.6	0.0	1,755.4	61.1	2,126.4	0.0	2,313.3	191.1
1996	1,161.2	0.5	5,969.3	203.1	3,810.2	0.0	1,020.6	0.0	1,836.1	68.5	1,977.7	0.0	2,089.2	256.6
1997	1,413.4	0.7	6,205.2	216.9	3,719.5	0.0	990.6	0.0	1,790.8	44.7	2,126.4	0.0	2,090.2	272.0
1998	1,451.5	0.0	6,286.8	182.6	4,291.0	0.0	1,085.0	0.0	1,741.8	52.7	2,175.4	0.0	2,177.2	313.7
1999	1,433.4	0.0	6,572.6	245.8	4,173.1	0.0	986.1	0.0	1,676.5	84.5	2,195.4	0.0	2,089.2	278.3
2000	1,544.0	0.2	6,477.3	272.2	4,305.5	0.0	1,147.6	0.0	1,486.0	126.2	2,086.5	0.0	2,131.9	253.6
2001	1,560.4	0.0	6,413.8	208.6	3,962.6	0.0	1,082.3	0.0	1,794.4	116.2	2,032.1	0.0	2,046.6	249.2
2002	1,690.1	0.3	7,261.1	423.3	4,245.6	0.6	1,073.2	0.0	1,931.4	227.6	1,845.2	2.8	2,267.1	306.7
2003	1,812.6	0.6	6,921.8	415.2	4,027.9	0.8	1,057.8	0.2	2,003.1	203.5	1,977.7	5.6	2,452.1	310.7
2004	1,785.3	0.9	6,667.8	357.9	4,281.9	1.8	1,065.9	0.1	1,872.4	172.9	1,930.5	11.7	2,177.2	400.1
2005	1,981.3	0.0	6,510.0	269.3	4,191.2	6.4	1,132.2	0.0	1,596.6	193.0	2,057.5	14.8	2,122.8	434.2
2006	1,882.4	0.0	6,785.7	277.8	4,408.0	8.6	1,151.2	0.0	1,716.4	179.4	2,032.1	14.0	1,955.9	380.1
2007	1,850.7	0.0	6,466.4	266.6	4,277.4	12.3	1,082.3	0.0	1,525.0	150.4	2,045.7	14.0	2,075.6	333.3
2008	2,028.5	0.0	6,540.8	304.7	4,510.5	14.7	1,175.7	1.9	1,524.1	210.3	2,095.6	34.6	1,636.6	405.8
2009	2,159.1	0.6	6,350.3	529.0	4,343.6	49.0	1,193.9	0.8	1,632.9	276.5	2,019.4	101.4	2,178.2	587.6
2010	2,082.9	5.5	5,737.0	571.5	4,305.5	20.0	1,092.3	1.8	1,619.3	247.8	1,959.5	26.4	2,041.2	501.7
2011	1,882.4	0.5	5,508.4	545.5	3,900.9	19.2	997.9	3.1	1,632.9	297.8	2,157.3	24.2	1,792.6	616.0
2012	1,905.1	0.1	5,470.3	657.2	3,773.9	35.4	958.0	2.8	1,516.8	284.5	1,859.7	53.1	1,689.2	594.1
2013	1,837.1	2.2	5,270.7	851.9	3,861.0	36.9	857.3	2.5	1,669.2	277.9	2,095.6	60.5	1,971.3	634.0
2014	2,004.9	4.3	5,164.6	729.5	3,856.4	15.2	1,066.9	1.2	1,397.1	245.3	1,839.8	84.1	1,790.8	586.9
2015	2,286.1	35.9	4,945.1	854.5	3,810.2	20.6	780.2	1.6	1,409.8	272.7	1,896.9	110.0	1,839.8	693.2
2016	2,223.5	118.8	4,572.2	1,139.2	3,991.6	2.6	798.3	7.5	1,790.8	401.1	2,019.4	119.2	2,028.5	756.5
2017	2,171.8	109.2	4,318.2	1,134.9	3,846.5	2.5	878.2	14.3	1,790.8	408.4	2,095.6	138.1	1,839.8	818.7
2018	1,957.7	156.1	3,880.9	936.4	4,000.7	1.6	789.3	12.5	1,562.2	370.0	1,678.3	192.7	1,428.8	831.0
2019	2,108.3	136.1	3,735.8	997.0	4,031.5	2.3	1,000.6	17.3	1,705.5	425.0	1,989.5	258.8	1,377.1	810.7
2020	2,004.9	113.4	3,102.6	1,112.1	4,123.2	14.0	698.5	20.9	1,502.3	434.9	1,896.0	223.2	1,636.6	787.1
2021	2,071.1	126.5	3,356.6	1,190.3	3,570.7	18.1	971.6	10.9	1,233.8	408.3	1,644.7	188.9	1,627.5	970.5
2022*	2,194.5	200.8	3,156.1	1,203.8	3,991.6	53.5	844.6	3.9	1,409.8	463.2	1,705.5	97.2	1,486.0	940.4

Table 2: Total Alfalfa Production and Export Volumes of the Seven Western States

Year	Total Alfalfa Production of the 7 Western States (MT)	Total Alfalfa Export from the 7 Western States (MT)	Total Alfalfa Production Exported (%)
1994	17,158,513	302,415	1.76%
1995	18,358,719	430,679	2.35%
1996	17,864,303	528,729	2.96%
1997	18,336,040	534,264	2.91%
1998	19,208,753	548,957	2.86%
1999	19,126,199	608,732	3.18%
2000	19,178,815	652,236	3.40%
2001	18,892,145	573,961	3.04%
2002	20,313,705	961,283	4.73%
2003	20,252,923	936,658	4.62%
2004	19,781,187	945,325	4.78%
2005	19,591,585	917,665	4.68%
2006	19,931,780	859,746	4.31%
2007	19,323,058	776,840	4.02%
2008	19,511,753	971,963	4.98%
2009	19,877,348	1,544,917	7.77%
2010	18,837,714	1,374,578	7.30%
2011	17,872,468	1,506,196	8.43%
2012	17,173,028	1,627,366	9.48%
2013	17,562,210	1,865,987	10.63%
2014	17,120,411	1,666,310	9.73%
2015	16,968,004	1,988,382	11.72%
2016	17,424,318	2,544,813	14.60%
2017	16,940,788	2,626,102	15.50%
2018	15,297,874	2,500,325	16.34%
2019	15,948,327	2,647,336	16.60%
2020	14,964,030	2,705,588	18.08%
2021	14,475,964	2,913,501	20.13%
*2022	14,788,036	2,962,720	20.03%

**2022 export volumes are estimated.*

Table 3. Estimated Low and High Ranges of Water Used for Alfalfa Exports in Seven Western U.S. States (Thousand Acre-feet)

State	Assumed Low and High Ranges of Water Use (acre-feet/acre)		2018 Irrigation Survey Avg. Water Use for All Crops	Exported Alfalfa's Water Use in 2022 (thousand acre-feet)		Exported Alfalfa's Water Use Over Last 5 years (avg., 2018-2022) (thousand acre-feet)		2018 Irrigation Survey, Irrigated Acres for all Crops	Range in Total Irrigation Water Utilized for Alfalfa Exports (%)	
	Low	High	(Acre-feet/Acre)	Low	High	Low	High	(Acres)	Low	High
Arizona	4.5	7.5	4.7	121	202	87	146	945,570	2.0%	4.6%
California	3.0	5.0	2.9	553	922	503	838	8,408,282	2.1%	3.8%
Idaho	2.0	3.0	1.9	27	41	9	14	3,393,063	0.1%	0.6%
Nevada	2.5	4.0	2.8	2	4	9	14	693,520	0.1%	0.7%
Oregon	2.0	3.0	1.7	232	348	219	328	1,579,108	8.1%	13.0%
Utah	2.5	3.5	2.0	65	91	135	189	1,181,700	2.8%	8.0%
Washington	2.0	3.0	2.2	399	598	411	616	1,866,110	9.7%	15.0%
Total			2.75 (wtd)	1,401	2,207	1,372	2,144	18,067,353	3.0%	4.8%