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Changes to California Alfalfa Production and Perceptions During the 2011-2017 Drought

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Abstract

California experienced a severe multi-year drought stretching from 2011-2017, significantly reducing surface water supply for ecosystems, agriculture, and humans, and prompting coordinated conservation efforts. Given that agriculture is the largest consumptive use of water in the state, one anticipated response to a severe drought would be to decrease production of low-value, high-water-use crops such as alfalfa. In this paper we use a multi-methods approach to examine both spatial distribution and public perceptions of alfalfa production in California over the course of the 2011-2017 drought. We find that while California alfalfa production did decline at the state level, it persisted and even increased in specific areas of the state. We also find that alfalfa persisted even though discourses and understandings that were critical of alfalfa production emerged in public forums during this time. We situate these findings within a broader context of California's water management system, which meant that in practice, infrastructure and water rights allocation practices left many growers with little incentive to change growing practices even in the face of serious meteorological drought.

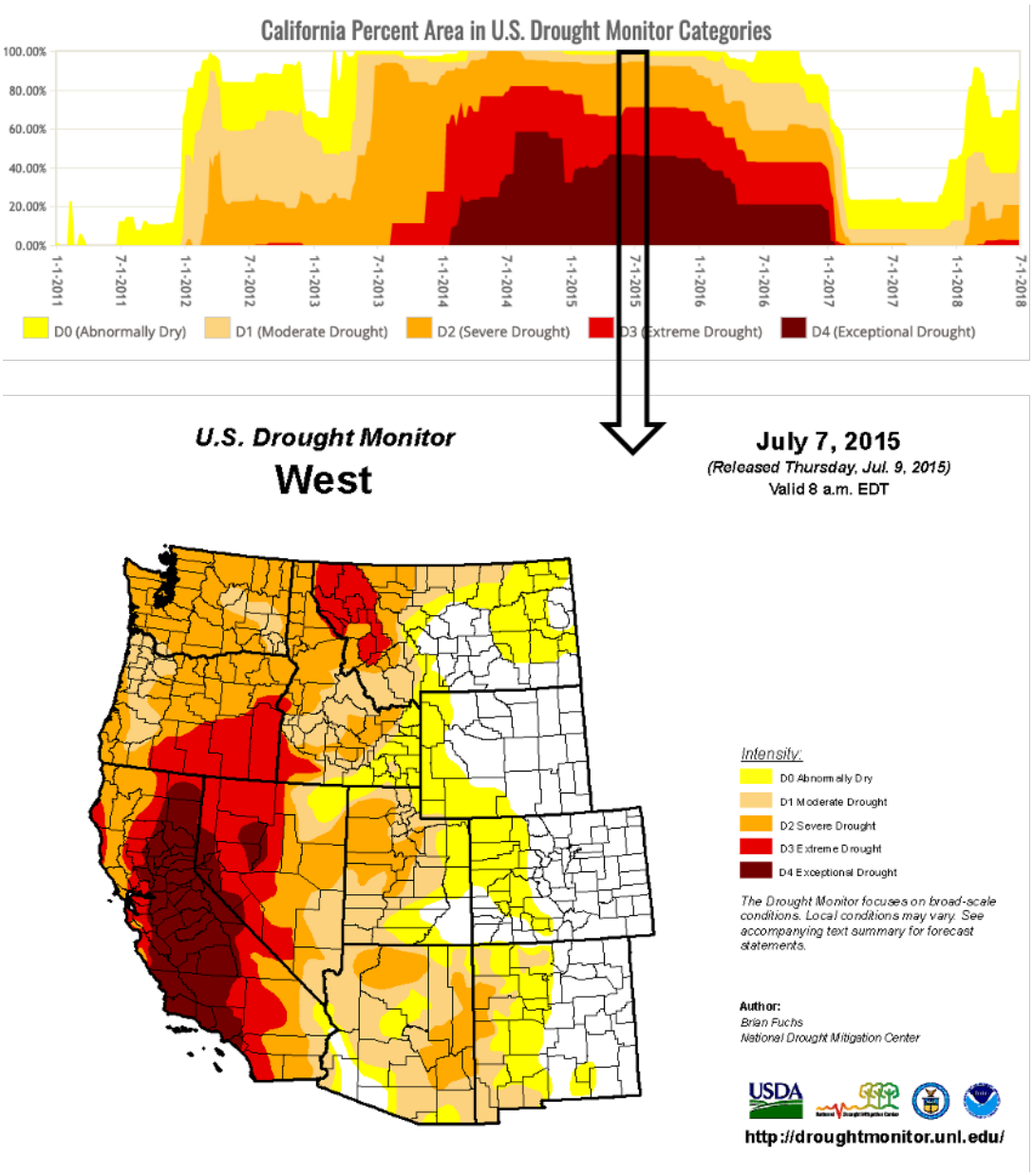
Keywords: *agriculture*, *alfalfa, California, drought, water governance*

Introduction

California is an increasingly water-stressed region with many competing water users and a long history of water issues. California has experienced drought over recent decades, exacerbating long-standing water management challenges. Eighty percent of the water that California uses for residential and business use goes towards irrigated agriculture, including production of water-intensive crops in some of the most arid regions of the state (Mount and Hanak 2019). Meanwhile, California has struggled to ensure enough water for endangered species and ecosystems.

California experienced a severe multi-year drought from 2011-2017 (Figure 1). This drought caused serious impacts, including damage to ecosystems, drying of residential water taps, and overdrafting of groundwater (Green Nylen et al. 2018; Lund et al. 2018). The drought extended across the Western United States, which further impacted California's water supply as the state draws significant quantities of water from the Colorado River Basin. During the drought, state water managers shifted to groundwater reserves to maintain agricultural production and make up for surface water shortages. Additionally, 6 percent of land statewide was fallowed (taken out of production purposely to save water) or stress irrigated (irrigated using less than full amounts of water) (Green Nylen et al. 2018; Lund et al. 2018).

Figure 1: Area of California experiencing drought from 2011-2018 (top); regional drought map of Western United States during height of drought (bottom). (U.S. Drought Monitor 2022)



A large quantity of California's agricultural water—around 15 percent, based on numbers from the California Department of Water Resources—is used for irrigating alfalfa (Cooley 2015). Alfalfa is a relatively low-value crop that serves as a key input to dairy and meat production systems. California is the leading alfalfa producer in the United States, producing five million

tons of alfalfa per year (California Department of Food and Agriculture 2021). When it comes to water-use efficiency ("crop per drop") as well as economic production and job creation ("dollars per drop" and "job per drop"), alfalfa falls short compared to many other crops: alfalfa is the single largest crop in terms of net water use, yet returns are low compared to other agricultural crops (Medellin-Azuara, Lund, and Howitt 2015). Still, one argument in favor of alfalfa production is that alfalfa increases overall system resiliency: it has been framed as "flexible" because it is easy to fallow or stop farming alfalfa if water is scarce (Fleck 2016). (This is in comparison to, for example, orchard crops such as nuts or fruits that must be watered every year.)

It might be assumed that a severe drought in a water-stressed region, like the one experienced in 2011-2017, would be met with a change in growing practices, particularly for low-value, high-water-use crops such as alfalfa. If alfalfa is a flexible crop, production would be expected to drop during drought. In this research we examine this assumption, striving to understand the degree to which alfalfa production actually changed in practice during the 2011-2017 drought. We first examined how changes in alfalfa production vary geographically by mapping changes in alfalfa production over the course of the drought. To understand more about the context in which these changes occurred, we then examined attitudes, perspectives, and understandings about alfalfa during the course of the drought through a news media analysis. By combining these different data sources, this research explores the relationship and contradictions between meteorological and agricultural drought (Wilhite and Glantz 1985), identifies discourses and framings in debates around water use, and contributes a stronger understanding of how water availability and scarcity are enacted in practice.

Background: Alfalfa production and water use in California

Alfalfa agriculture

Alfalfa is a perennial flowering legume plant frequently grown for hay to feed to cattle. It is considered one of the most important forage crops in the world because of its high nutritional value for livestock. Alfalfa can be harvested anywhere from two to twelve times per growing season, depending on climate and water application. Alfalfa is grown for the large cattle and dairy industry in California, and is often exported (Matthews et al. 2016). Globally, the alfalfa hay market has grown significantly in recent years due to growing worldwide demand for dairy (Research and Markets 2018). The United States is the top producer of alfalfa worldwide and is a major exporter of alfalfa hay. After cotton, alfalfa represents the second-largest share of irrigated acreage of U.S. field crops, accounting for 35 percent of total U.S. irrigated acreage (Hellerstein, Vilorio, and Ribaudo 2019). Within the U.S., California has long been a top alfalfa producing state and has the highest yield per acre of alfalfa of any state (USDA 2013; Research and Markets 2018).

Alfalfa production in California requires high water use compared to both urban usage and other crops, including other crops used to feed livestock (FAO 2021; Fleck 2016; Lund et al. 2018; Medellín-Azuara and Lund 2015). Alfalfa is often flood irrigated, an inefficient irrigation strategy compared to more efficient irrigation techniques such as drip or sprinkler systems. While one argument justifying water use for agriculture in general is that it creates jobs and drives economic production (Medellín-Azuara and Lund 2015,2021), alfalfa production creates

very few jobs directly compared to other water-intensive agricultural crops since its production is highly mechanized (although it does support the dairy industry in California and worldwide).

Some water resources scholars have argued that despite alfalfa's large water footprint, the crop has an important role in supporting a larger picture of water use and agriculture (Fleck 2016; Putnam 2015). For example, Colorado River water scientist John Fleck (2016) argued that one benefit of alfalfa is that it is flexible. Fleck makes the case that alfalfa is an important crop due to seasonal flexibility, and argues that planting alfalfa is beneficial compared to, for example, planting almonds (which lack flexibility since they must be continually irrigated) or fallowing fields (which takes land out of agricultural production altogether). Agronomist Daniel Putnam (2015) adds that alfalfa does not really use more water than other crops, but instead, its high water use is simply attributable to high acreage and intensive cropping.

This framing of alfalfa as a flexible crop includes an embedded assumption that individual farmers will respond to water availability year to year and reduce alfalfa production accordingly. However, studies show that farming decisions are not always linked to meteorological conditions. For example, one study found that farm output of tree nuts and fruit in California was maintained during the drought (Tortajada et al. 2017), and almond plantings even expanded (Cooley et al. 2015; Green Nylen et al. 2018). Tortajada et al. (2017) found that perennial production in California was maintained throughout the drought due to groundwater availability and legal and institutional decision making. This raises several important issues which we examine further in this paper: first, the disconnect between meteorological drought and agricultural practices, and second, the importance of legal and institutional structures,

particularly water rights, in shaping agricultural practices and decisions. As such, we next turn to water resource governance literature.

Water resources governance

Our research is informed by broader geographic and political ecological analysis about the social and political dimensions of water use and access (Linton and Budds 2014; Swyngedouw 2007), and is situated within regional analyses of the U.S. West which describe the long history of power struggles over water management in California and the Western U.S. (Reisner 1986; Worster 1985). There has been a large body of recent work in political ecology on power and politics of water, which includes, for example, regionally-based studies of 'hydrosocial territories' that examine the interconnected social, environmental, and infrastructural dimensions of water (e.g., Cantor 2021; Cantor and Ross 2021), as well as studies that uncover how water infrastructures have left a legacy of Indigenous displacement (Curley 2021; Dallman et al. 2013).

Water law is a key factor in shaping water allocation. Scholarship in legal geography, which examines the co-production of place, space, and law, has noted the key role of water rights in shaping California's landscapes and waterscapes (Cantor 2016; Cantor 2017). There have been multiple studies examining how water use for agricultural production in California was maintained during the drought through legal and institutional strategies at the local, state and federal level (Green Nylen et al. 2018; Huckleberry and Potts 2019; Tortajada et al. 2017). California's water management has been described as a "hidden government of water resources" (Polk 2015) suggesting that water rights systems in the US West are not transparent and lack meaningful public attention and debate.

Access to water in California is shaped by prior appropriation, a legal doctrine in which water rights are allocated "first in time, first in right." Older water rights are senior to (and thus more secure than) more recently obtained water rights (Grantham and Viers 2014). California's water rights system is both highly complex, with over 12,000 separate rights allocated, and highly opaque, with many water rights only existing in paper form even in the 21st century (Kiparsky et al. 2021). The California Water Board has allocated five times more water than the state's annual supply; junior water rights are subject to curtailment during drought (Grantham and Viers 2014; Green Nylen et al. 2018). Senior water rights holders are disincentivized to curtail their water use due to the "use it or lose it" clause, which means that water rights can be reduced if they are not being used to their full extent (Lustgarten 2015). Water experts have pointed out that the use it or lose it clause could compel senior water rights holders into maintaining production of water-intensive crops such as alfalfa, versus incentivizing or compelling non-use of water in a drought (Leonard et al. 2021). This water rights system, which compels water use to maintain rights and concentrates water access to the longest-standing holders, has been described by many scholars as inadequate, "a formidable change-resistant institution" (Anderson et al. 2018, 199), and a hindrance to water conservation (Leonard et al. 2021).

Given the importance of legal structures in shaping water allocation, any discussion of grower decision-making about cropping must be contextualized in broader questions of water resource governance and law. In this paper we consider how the expectation that alfalfa production will change due to physical water availability does not account for the context of water rights, and

argue that alfalfa production and agricultural trends must be considered within political, economic and legal contexts.

Methods

We focused on questions of (a) whether, in practice, farmers transitioned away from alfalfa during the 2011-2017 California drought, and (b) how the drought affected awareness and discourses around water management. We employed a mixed-methods approach to develop a fuller understanding of these questions. Despite practical difficulties, mixed methods are useful for bridging qualitative-quantitative divides in human geographic research, enhancing explanatory power through integrating different types of data and analysis in order to triangulate and gain new insights (Elwood 2010). Political ecologists in particular have argued for the importance of using mixed methods—in a careful and critical manner—to more fully understand complexities of human-environment systems (Rocheleau 2008; Turner 2015).

To understand more about how and why alfalfa production changed or persisted during the drought, we examined spatial distribution and change alongside media discourses to understand how ideas about alfalfa production shifted during the drought. This mixed-methods approach provides a richer understanding of water use practices under drought conditions. We first describe our spatial methods, then describe our media analysis.

Mapping alfalfa production patterns

We utilized GIS methods to analyze alfalfa crop production for the state of California on the county scale to understand changes in production over the course of the drought. Agricultural

reports sourced from the USDA's National Agricultural Statistics Service California Field Office were downloaded as Excel CSV files for years 2011-2017 and were edited to display only alfalfa crop data. These tables were then brought into a GIS system, QGIS, where they were linked spatially to a California county shapefile and displayed on a map, allowing us to view spatial changes in alfalfa crop production and observe noticeable spatial trends.

Based on initial analysis of alfalfa production, we narrowed our research parameters from the state level down to two specific regions that included the ten highest alfalfa-producing counties in the state: the southern Central Valley region (also sometimes called the San Joaquin Valley, hereafter "Central Valley"), which included Fresno, Kern, Kings, Madera, San Joaquin, Stanislaus, Merced, and Tulare Counties; and the southern Imperial Valley region (hereafter "Southern") consisting of Imperial and Riverside Counties. We also included all other counties that reported alfalfa production in another category called "Other" to compare our two specific regions to the rest of the state.

Once regions were grouped, we analyzed and compared alfalfa production within Excel. We gathered all counties reporting alfalfa production between 2011-2017 into a list, then separated that list by our three regions: Central Valley, Southern, and Other. We examined several metrics, including tons of alfalfa produced (to capture the total amount produced) and harvested acres of alfalfa (to capture the geographic extent of production). We added in each county's alfalfa production and harvested acres data into a table for three years which served as benchmarks for the drought: 2011 (beginning of drought), 2014 (middle of drought), and 2017 (end of drought). We subtracted 2011 alfalfa data from 2017 data, for both production and

harvested acres, to find the total change during this time period. The calculated "change" amount was compiled by region and totaled. We then normalized alfalfa change data to make up for the obvious size differences between regions. To do this, each region had a shapefile created for it in QGIS where we were then able to use the field calculator function in QGIS to find the area in acres for each region. This regional area data was then input into our alfalfa data change table where it was then used to divide production change and harvested acres. The final result was a more accurate measurement of alfalfa crop change between 2011 and 2017 that controlled for region size.

Media content analysis of public discourses and opinions around alfalfa

We conducted a media content analysis to understand how public discourses around alfalfa production emerged and evolved during the drought. Media content analysis is a technique that uses quantitative and/or qualitative methods to analyze content and characteristics of messages in media (e.g., news, magazines, television, etc.) (Macnamara 2005). We follow scholars who have used the concept of media frames to identify discursive patterns and constructions and ways of understanding events (Kelly 2010; Matthes and Kohring 2008).

We focused on newspaper materials, including news articles and opinion columns, as a way to understand framings of the drought event and its relationship to alfalfa production (Earl et al. 2004). We examined five different newspapers representing different geographic scales and locations: three local/regional newspapers (Bakersfield Californian, Fresno Bee, and The Desert Sun), one state newspaper (Los Angeles Times); and one national newspaper (New York Times). These papers were chosen for relevancy, geography, and robustness of archives. We first

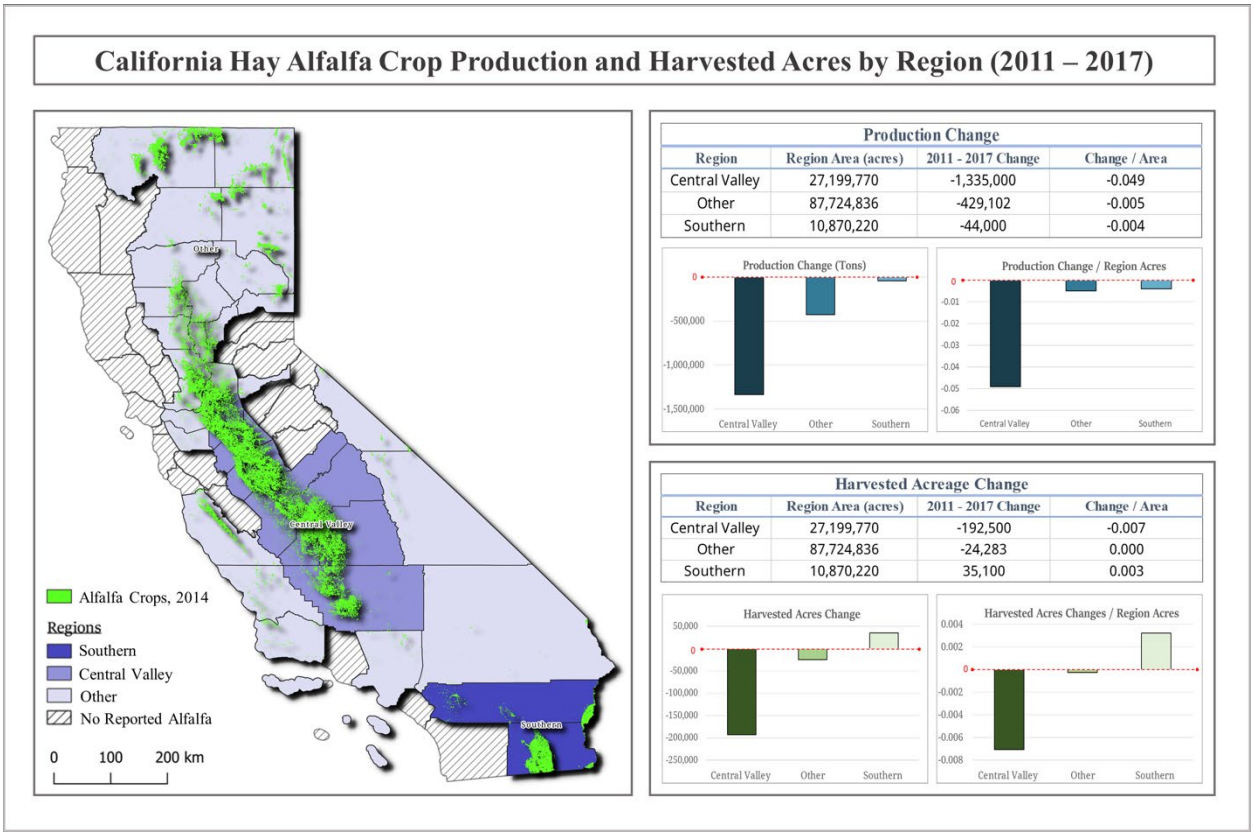
examined archives of the five newspapers to develop a data set of articles about alfalfa and drought. We included news articles and opinion pieces that were: (a) published during 2011 to 2017; and (b) included both the words "alfalfa" and "drought," except for the New York Times where we also included the word "California" in our search. This gave us 176 articles. We then excluded irrelevant articles (for example, articles about a town called Alfalfa, or articles about the Little Rascals character named Alfalfa) to develop a relevant dataset of ninety-six articles. We wrote summaries of each article and conducted an initial emergent coding process to identify the most common frames being used to discuss alfalfa production; then used these emergent themes to code within the articles.

Results

Shifts and persistence in alfalfa production patterns

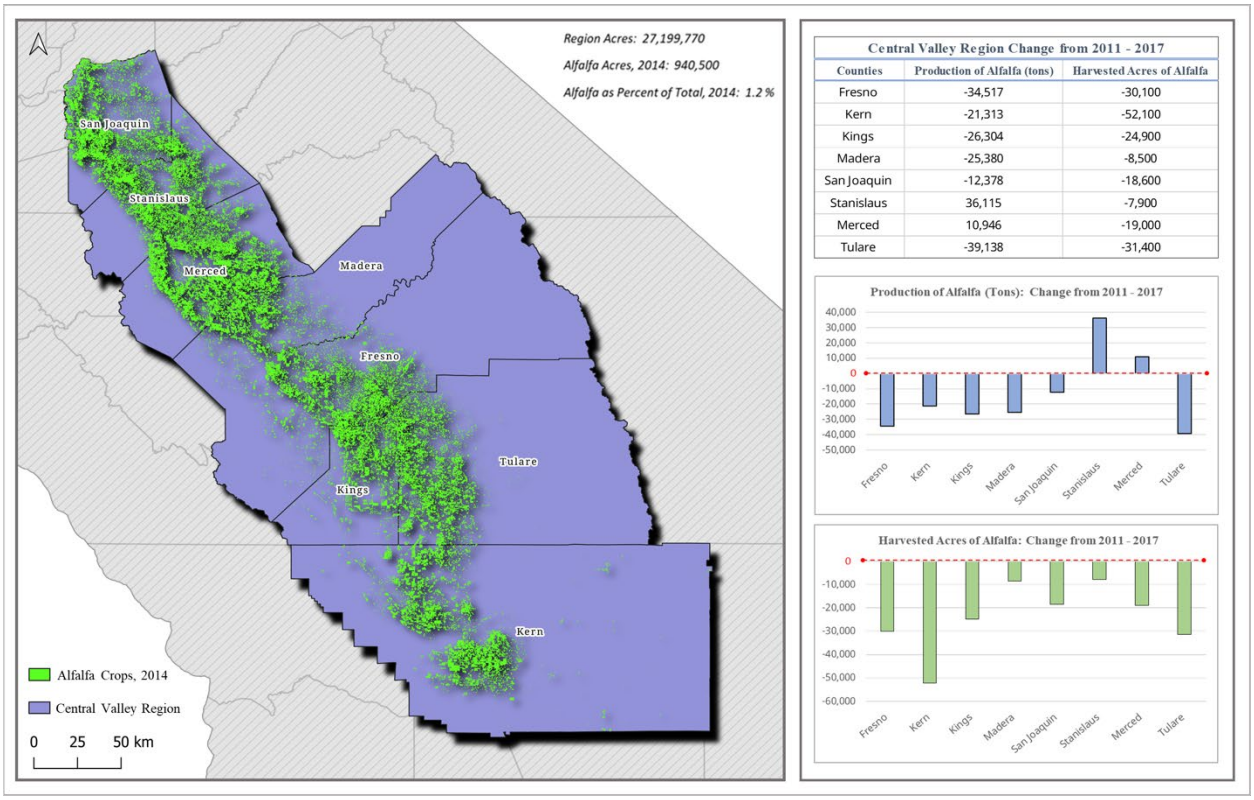
Mapping alfalfa distribution across California revealed several distinct regions responsible for the majority of alfalfa production: the southern part of California's Central Valley, and Southern California's Imperial Valley. We found notable regional variance in the alfalfa production over the drought period (Figure 2). Alfalfa production in the Central Valley region decreased markedly during the drought, as measured both by tons of alfalfa produced and acres of alfalfa harvested. Both in absolute terms and when adjusted for total region area, the Central Valley decreased overall production and land used for production of alfalfa much more than the rest of California. In contrast, alfalfa production in Southern California not only persisted but actually increased in some areas during the drought. Both in absolute terms and when adjusted for total region area, Southern California's alfalfa production in tons stayed approximately the same over the course of the drought; the land used to grow alfalfa expanded during this time period.

Figure 2: Map (left) shows alfalfa production lands in 2014; graphs (right) show changes to alfalfa production (tons of production and harvested acres) across California, 2011-2017



Focusing on the Central Valley region (Figure 3), we found that every county except for Stanislaus reduced production of alfalfa, measured in tons, between 2011-2017. Every county (including Stanislaus) reduced harvested acres of alfalfa during this time period. This implies that Stanislaus County may have intensified production during the drought, perhaps harvesting more cuttings on the same acreage, to increase production on decreased acreage. Yet as a whole, the region decreased alfalfa production and land used to grow alfalfa during this time period.

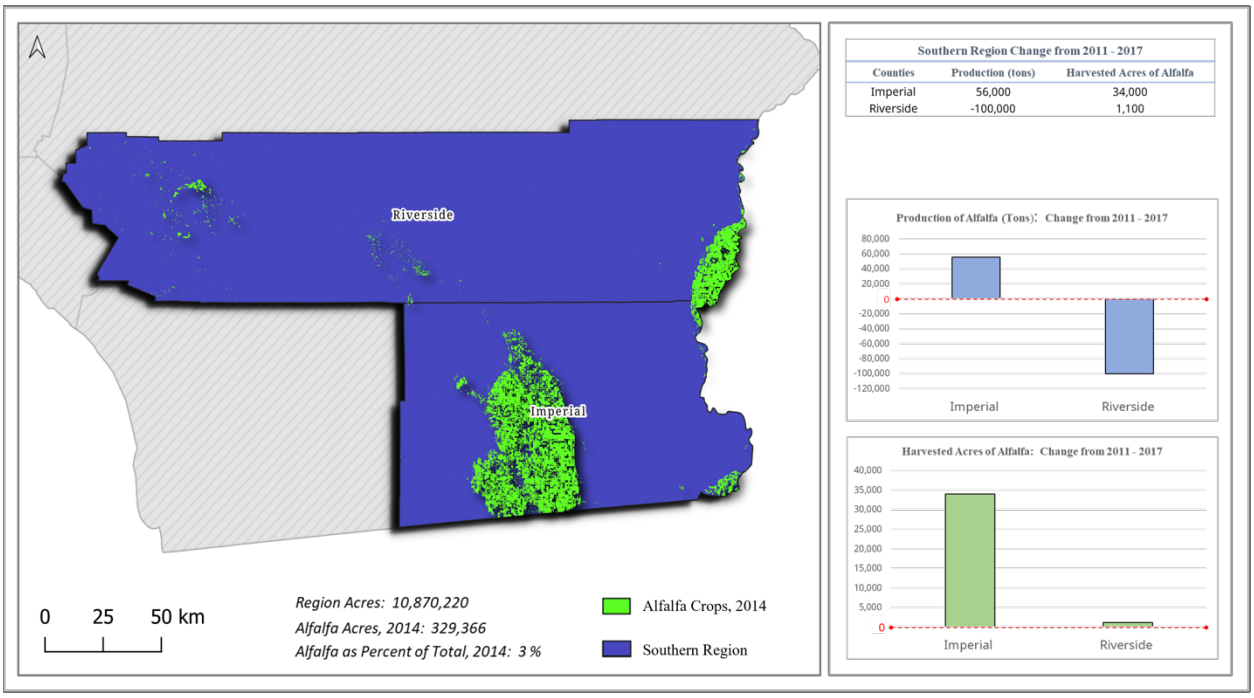
Figure 3: Map (left) shows Central Valley alfalfa production lands in 2014; graphs (right) show changes to alfalfa production (tons of production and harvested acres) in largest Central Valley alfalfa producing counties, 2011-2017



Central Valley Region Change from 2011 - 2017		
Counties	Production of Alfalfa (tons)	Harvested Acres of Alfalfa
Fresno	-34,517	-30,100
Kern	-21,313	-52,100
Kings	-26,304	-24,900
Madera	-25,380	-8,500
San Joaquin	-12,378	-18,600
Stanislaus	36,115	-7,900
Merced	10,946	-19,000
Tulare	-39,138	-31,400

Examining the two alfalfa producing counties in Southern California (Figure 4), we found that Riverside County reduced alfalfa production in tons, although harvested acreage remained about the same, which implies that they harvested fewer cuttings, produced less intensively, or fallowed lands for part of the year. Imperial County, however, *increased* production of alfalfa measured in tons as well as harvested acreage of alfalfa during the drought time period. Imperial County accounts for nearly all of the growth in alfalfa lands in this region.

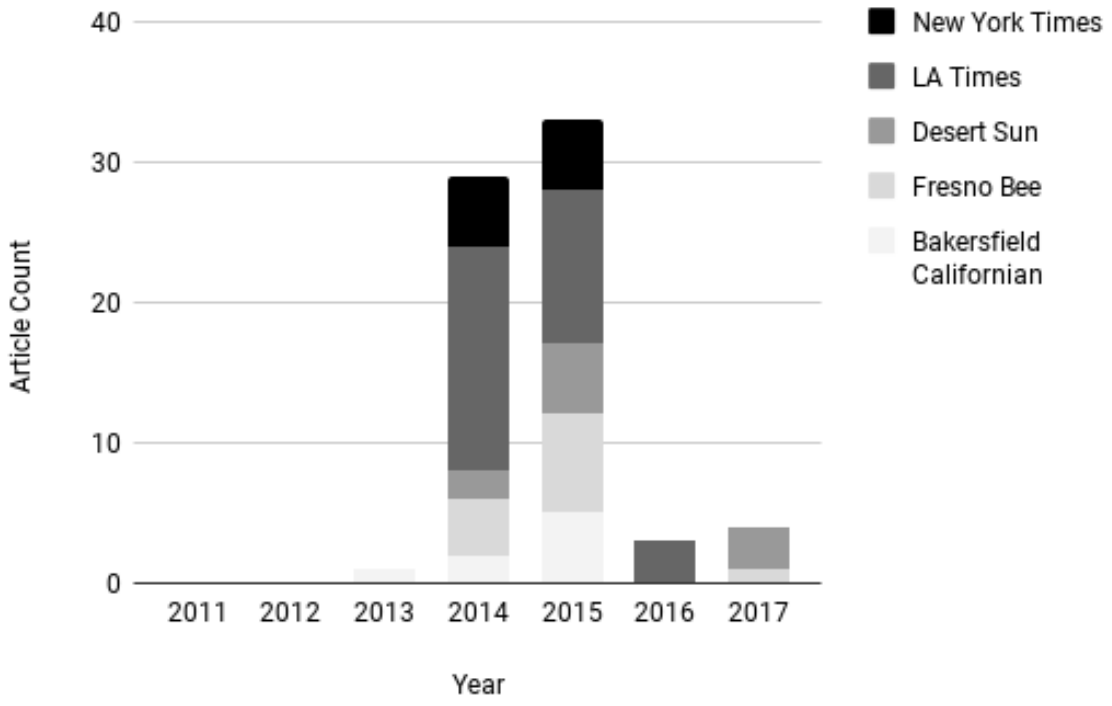
Figure 4: Map (left) shows Southern California's alfalfa production lands in 2014; graphs (right) show changes to alfalfa production (tons of production and harvested acres) in Southern California's Imperial Valley, 2011-2017



Public discourses on drought and alfalfa

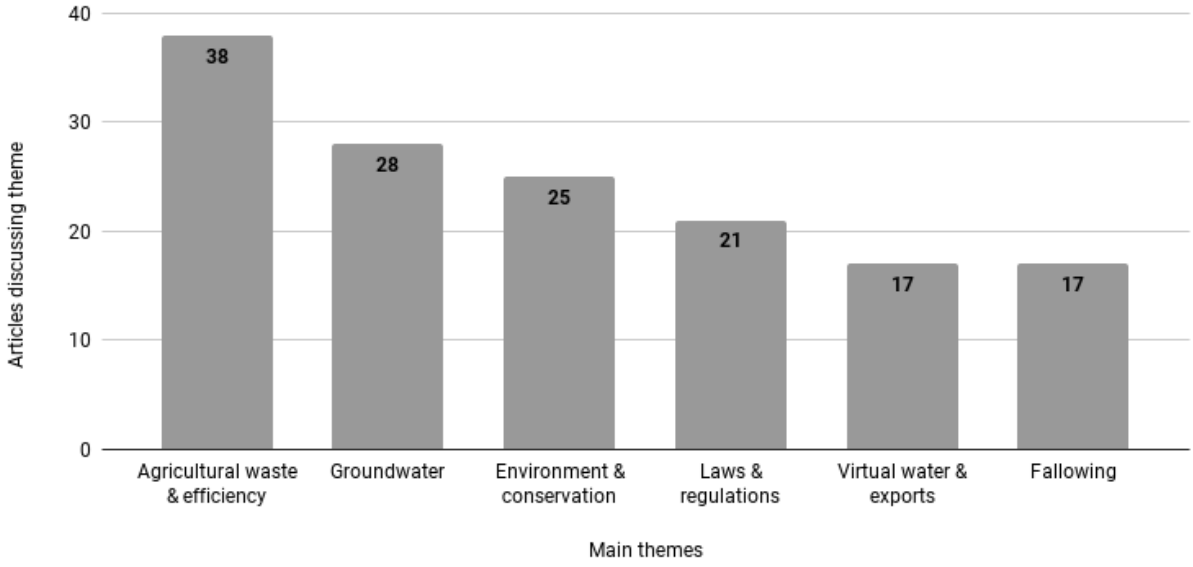
We examined media coverage of drought and alfalfa in local, regional, and national newspapers to gain a more nuanced understanding of why alfalfa persisted through the drought. Media coverage of alfalfa and drought peaked between 2014-2015 (Figure 5). Between 2011-2013, media coverage was sparse as the drought was in its infancy and its effects were not yet widely felt. Between 2014-2015, the drought was making front-page news as drought management programs took effect. Between 2016-2017 the drought fell out of media coverage.

Figure 5: Frequency of news articles mentioning alfalfa + drought, 2011-2017



We next identified major themes in the news articles (Figure 6). Figure 6 shows how frequently each of the main themes were mentioned across the articles we examined.

Figure 6: Main themes discussed in articles about alfalfa and drought, and frequency of articles discussing each main theme.



What emerged from the news articles was a complex picture of understandings of alfalfa production and drought, which included many different and sometimes conflicting perspectives. Table 1 provides descriptions and examples of each of the main themes we identified.

Table 1: Summary and examples of the most prevalent themes in news media

Theme/code	**Summary of theme**	**Example quote/ passage from news media**	**Source**
Agricultural waste & efficiency - critical of ag	Agricultural water use is inefficient or wasteful.	"Farmers continue to grow alfalfa, rice and other thirsty crops. Their resource use has been heavily subsidized by the government… farmers have no incentive to irrigate their farmlands efficiently."	New York Times, 3/16/2014. "What to do about California's drought." Opinion by Jagjit Singh
Agricultural waste & efficiency - supportive of ag	Agricultural water use is efficient; it is needed to produce food.	[Almonds] "have been steadily taking over from cotton and lettuce because they are more lucrative. "That's the highest and best use of the land," said Ryan Metzler, 45, who grows almonds near Fresno."	New York Times, 12/27/2014. "Water source for almonds in California may run dry." News article by Felicity Barringer
Environment & conservation-supportive of conservation	Water conservation is needed to manage drought.	"Every drop really does count. Wise use and conservation — not new dams, not desalination — are the answers, and conservation means common sense should take precedence over profiteering."	New York Times, 9/27/2017. "Making sense of water." Opinion column by Mark Bittman.

Environment & conservation-critical of conservation	Environmentalists have taken water away from people in the name of conservation.	"Environmentalists flushed 3.9 billion gallons of water — enough for 174,300 people for a year — to benefit a miniscule number of fish. These people want to use 3.6 billion more gallons to benefit an even smaller amount."	Desert Sun, 9/27/2015. "What water shortage?" Opinion column by Richard Mack
Groundwater	Groundwater has been overdrawn; groundwater needs to be better managed.	"An implicit assumption is that when there is a gap in supply, everyone can fill the gap with groundwater. Groundwater is mostly unmanaged. We won't be able to rely on that reserve without long-term management."	Los Angeles Times, 2/19/2014. "Jay Famiglietti's mission: to rescue us from our bad water habits." Opinion column by Pat Morrison
Laws & regulations	California's water rights system is a problem in times of drought.	"Calls for restrictions on agricultural water use have flared alongside questions about California's system of water rights, under which farmers with seniority haven't had to cut back."	Desert Sun, 5/8/2015. "Farm water use comes under scrutiny." News article by Jesse Marx and Ian James.
Virtual water	It is problematic to export high water use crops like alfalfa to foreign countries.	"It's outlandish, urban critics note, for big farm units to be growing alfalfa — which consumes about 20 percent of the state's irrigation water… And by exporting that alfalfa and other thirsty crops overseas, the state is essentially shipping its precious water to China."	New York Times, 5/1/2015. "The end of California?" Opinion column by Timothy Egan.
Fallowing	Fallowing fields to save water damages agricultural production & livelihoods.	"Many farmers here argue that fallowing land is simply a wrongheaded approach to freeing up water supplies because it reduces the amount of productive land being used to grow crops such as carrots, lettuce and wheat that thrive in the Imperial Valley. "When you fallow, you create a lot of problems. You put people out of work," said Al Kalin, a lifelong farmer."	Desert Sun, 3/16/2014. "Imperial Valley farmers being paid by IID to fallow fields." News article by Ian James.

We identified two main conflicting framings within the news articles. The first frame, which we call "ag-water-supportive," saw agricultural water use as essential to global food production, rural economies, and livelihoods in agriculturally-based communities. The second frame, "ag-water-critical," viewed agricultural water use as largely wasteful or inefficient, particularly when used for high-water-use crops like alfalfa. In particular, this frame emphasized critiques of so-called "virtual water," the export of water in the form of alfalfa, almonds, and other water-intensive agricultural crops. Virtual water was particularly discussed in the context of large-scale agricultural land purchases, including purchases of California farmland by foreign entities, and

transfers of water from rural land in Riverside and Imperial counties to urban Southern California.

The articles also discussed the impacts of drought mitigation efforts. The two frames emerged again in the form of contradictory perspectives on water conservation measures. In general, supporters of agricultural water use saw water conservation efforts as limiting farmers' access to water and were concerned this would put their financial stability in jeopardy. Agricultural water supporters tended to favor large water infrastructure projects (though none were actually built during this time period). Fallowing was highly criticized as an engine to drain rural communities of their water for the large coastal cities. However, many agricultural water supporters saw fallowing as a necessary evil to stay afloat during the drought.

For those who saw agriculture as wasteful, however, water conservation efforts were seen as essential to mitigating drought, securing supply of water for people outside of agriculture, and protecting the environment. The majority agreed that fallowing was not practical to continue after the drought was over, but saw it as an important temporary strategy. Agricultural water critics frequently pointed to market-based solutions (such as selling or leasing water) to incentivize agricultural conservation.

Groundwater depletion related to the common practice of farmers relying upon groundwater to make up for decreased surface water availability was raised as a particular issue of concern that needed to be mitigated. Agricultural water supporters and critics agreed that groundwater depletion and overpumping was a problem.

Finally, the articles discussed the drivers of inefficient or problematic water use during drought. Supporters of agricultural water use argued that urban water users should do more to conserve,

since they are not producing food. In contrast, those who saw agriculture as wasteful pointed to water allocation laws and regulations, particularly the prior appropriation water rights allocation system, which was seen within this frame as a driver of inefficiency during drought.

Table 2: Summary of perspectives on agricultural water use, drought mitigation efforts, and problematic water use during drought.

	Frame 1: Ag-water-supportive	Frame 2: Ag-water-critical
Perceptions of agricultural water use	Agricultural water use creates jobs and food, and supports rural communities.	Agricultural water use is wasteful and inefficient, in particular when 'virtual water' in the form of alfalfa and almonds is exported.
Perceptions of drought mitigation efforts	Growers need water to be economically productive and support their communities, and shouldn't have to give up water to support cities. Fallowing harms rural communities.	Drought mitigation, including fallowing, is essential to mitigating drought and protecting non-agricultural water users, environments, and groundwater.
Perceptions of problematic water use during drought	Urban water users are not producing food and should be the ones to conserve water.	Outdated water allocation laws and water rights systems are responsible for driving inefficient water use during drought.

Discussion

Our analysis revealed an uneven picture of alfalfa during California during the 2011-2017 drought, both in terms of actual production as well as public perception and understanding. Alfalfa production declined overall at the state level, particularly in the agriculture-heavy Central Valley. Yet in Southern California's Imperial County, alfalfa production actually increased during the drought. This increase was in spite of the obvious presence of meteorological drought as well as significant public attention in the form of news media focused on the connections between drought and alfalfa production.

The mapping analysis showed that the relationships between meteorological water availability and crop production are not necessarily tightly related to one another. Localized meteorological drought is clearly not the only driving factor determining production capacity. Instead, California's water allocation policies and practices play a more important role. First, infrastructure is key. The two regions we focused on—the Central Valley and Southern California's Imperial Valley—import their water from different sources: the Central Valley draws primarily from the State Water Project, which moves water from Northern California to the Central Valley, while Southern California's agricultural areas receive large water allocations from the Colorado River Basin. The Colorado River Basin was also affected by drought during this time, but not as severely as California, meaning that Southern California's water source was less stressed than that of the Central Valley despite the presence of meteorological drought affecting nearly all of California (Figure 1). Second, water rights matter. Southern California's irrigation districts hold very secure senior water rights to large quantities of valuable Colorado River Basin water, meaning that even in a severe meteorological drought, they continue getting their full allocation of surface water. This water rights structure disincentivizes conservation practices such as crop shifting or fallowing for senior water rights holders, which holds true with what we observed in Imperial County in particular. Meanwhile, the Central Valley's growers hold a much more mixed portfolio of junior and senior water rights (Maestu 2020) and even senior water rights holders in this region have recently faced significant pressures to reduce water use to support drought-threatened ecosystems (Becker 2021). Growers in this region turned to less-regulated (but still overdrawn) groundwater sources to make up for surface water deficits. Availability of water for agriculture is thus not only a factor of the amount of rain that

falls locally, but of water infrastructure and water rights across a much broader region (Cantor 2021).

The media analysis revealed markedly different framings used to describe agricultural water use and the impacts of drought mitigation strategies. Framings on alfalfa production were situated within broader understandings around the proper role of agricultural water use. Alfalfa was not necessarily the main target of those concerned with water in the drought, but rather, as a high water use crop, alfalfa was frequently used as emblematic of broader problems, a lens to view challenges of managing water in a drought. In the ag-water-supportive frame, water use for agriculture, including alfalfa, was seen as important to feeding the world and protecting agricultural jobs and communities. From this perspective, drought management techniques, primarily fallowing, were reluctantly participated in, but were seen as negative for agriculture and rural economies if they persisted and became the norm. In the ag-water-critical framing, alfalfa represented an inefficient use of water, particularly when grown for export as virtual water. Articles and sources grounded in the ag-water-critical frame communicated a detailed understanding of the sometimes technical and complex issue of water rights, laws, infrastructure, and allocation practices to a public audience, and noted the need to change these physical and legal infrastructures. Notably, beyond promoting urban lifestyle changes (running water less, not watering lawns, etc.), solutions from ag-water-critical sources revolved largely around increasing the use of markets in water.

Overall, the production of alfalfa during the drought was not simply a factor of meteorological water availability, nor was it impacted by public understandings in a straightforward way. Legal

processes of water allocation were understood, particularly within the ag-water-critical frame, as crucial in shaping the landscape of alfalfa production. Because Southern California's agricultural water users have senior rights to large quantities of water under the prior appropriation system, even during drought times they receive full water allocations. In practice, this meant that growers with secure water rights had no incentive to change their growing practices even in the face of the serious drought paired with social pressure to reduce water use. While the public was presented with resources to gain a stronger understanding of this set of water allocation processes via the media coverage of the drought, there was not an effective way to translate this increased public understanding into policy or regulation that could actually change water use practices.

Conclusions

The goal of this research was to examine what happened to alfalfa production during the course of the recent California drought, and whether alfalfa is really a flexible crop that is adjusted during times of drought versus times of plenty (Fleck 2016). We conclude that alfalfa did not change significantly in response to either meteorological drought or public awareness during California's 2011-2017 drought. Alfalfa production persisted in uneven ways across the state, responding to actual availability of water for agriculture, which is not just a function of precipitation but is legally and politically determined. The importance of law and policy was evident in media articles that explicitly connected water use to laws and policies; yet, this public understanding of water law and policy did not necessarily drive actual policy change. Together, our mixed-methods analysis points to the need to understand drought as situated in place and heavily shaped by legal-political systems, not just weather patterns. That is, drought is not just a

meteorological phenomenon, but a legal geographical issue, in which water availability is shaped by place-based legal systems of allocation.

Given that alfalfa is such a large water user in the Southwestern US, there is a significant need for further critical engagement around this crop. First, future research could directly study alfalfa producers' perspectives through interviews or surveys to better understand decision making practices and opinions on water conservation policies. Second, while we focused our mapping analysis to examine shifts to alfalfa production over the course of the drought, future spatial analysis could examine more complex tradeoffs and spatial relationships between factors such as alfalfa production, almond production, other crops, groundwater depletion, domestic well depletion, and ecosystem degradation. Third, further studies could focus on the broader networks and economic structures of alfalfa production, for example, studying the shifting virtual water trade networks involving alfalfa, the role of international trade policies and laws, and international dietary shifts that may be driving international alfalfa demand and trade.

Changing legal systems may shift agricultural production practices during drought going forward. For example, California's Sustainable Groundwater Management Act (SGMA) was passed in 2014, representing the first statewide mandate to attempt to manage groundwater resources sustainably (Leahy 2015). SGMA represented a historic legal change meant to encourage more sustainable management of scarce water resources. Groundwater is often used as a buffer when surface water availability is low, and farmers have historically overpumped groundwater resources to make up for surface water shortages. Because the new law has a relatively long implementation timeline, its full effects remain to be seen, but the law does hold

potential to change the practice of using groundwater as a buffer and could impact future agricultural practices during times of drought. While it is unclear exactly how to attribute the shifts in alfalfa production that we did see, we note that the largest reductions of alfalfa production occurred in the most heavily groundwater-reliant region of California (the San Joaquin/ southern Central Valley). Other existing laws such as California's "waste and unreasonable use doctrine" hold potential to shift agricultural practices during drought, as well (Cantor 2017; Gray 2015). More recently, in California's 2020-2021 drought, senior water users in the Central Valley did face pressure to reduce water use given the severity of drought and its impact on ecosystems (Becker, 2021). Increased public awareness and a more nuanced and complex public understanding of how water allocation laws and policies shape water management during drought could potentially drive future public pressure for policy change.

At the time of writing, California is once again experiencing a multi-year drought, and dry periods appear likely to occur again in the future with climate change (Bales 2021). Based on our research, we emphasize that water use during drought is strongly shaped by factors beyond physical water availability or meteorological patterns—in particular water infrastructure and legal structures of water rights. Assuming that growers are rational actors who will change their crops according to meteorological drought does not account for these legal and physical infrastructures. Whether growing awareness of the structures shaping water allocation will lead to a more informed public that demands reform of water rights in the future remains to be seen. Given alfalfa's outsized role in Western US water use, we hope future scholarship continues to examine this important and evolving topic.

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