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On-ranch adaptation to California's historic 2012-2016 drought

By Grace Woodmansee, Dan Macon, Tracy Schohr and Leslie M. Roche

On the Ground

- California's historic, statewide drought (2012-2016) challenged the ability of ranchers to adapt to unprecedented conditions while maintaining the economic and ecological sustainability of their operations.
- We examined how California's historic drought shaped on-ranch drought impacts and management strategies via two separate research efforts: The California Rangeland Decision-Making Survey (2011) and semistructured interviews conducted during the drought (2016).
- The average number of drought management practices used by ranchers increased between 2011 and 2016; in particular, an apparent increase in use of proactive practices may indicate that underlying drought conditions leading into 2012 were a catalyst for proactive drought planning.
- Rancher responses to questions about future drought risk suggest drought experience impacted individual perceptions of threat and preparedness in two distinct ways. Ranch managers believed that 1) drought will be more influential in their future management planning, and 2) their current management strategies would be adequate to mitigate future drought impacts.
- Decision-support tools to help ranchers match their preferred proactive strategies with cost-effective, operation-specific reactive strategies can increase the use of science-based decision-making during drought.

Keywords: adaptive management, climate change, decision-making, drought, livestock production, ranching.

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Introduction

Over the past decade, historic drought conditions have ravaged western rangelands and the communities that depend on them. Although drought is an important driver of ecosystem dynamics, recent increases in intensity, frequency, and severity of drought have created unprecedented impacts across the western United States. Although there are multiple types and definitions of drought depending on scale and impacts of interest, drought is generally regarded as a climate water deficit resulting in negative ecological, economic, and social effects.[1–4] Increasingly severe drought impacts are attributed to the interacting effects of expected (or "normal") short-term drought conditions with long-term soil moisture deficits driven by climate change.[5–7] The 2000 to 2018 megadrought across southwestern North America clearly demonstrated these interacting effects: natural precipitation variability coupled with anthropogenic warming resulted in the second driest 19-year period since 800 CE.[6] Recent work has found that these severe and highly variable drought conditions are not affecting all communities equally—urban populations are often buffered from potential drought impacts for a number of reasons, including wealth and geographic location (i.e., exposure to risk).[5,8] Rural, agricultural communities are often the first impacted by drought, as many livelihoods in these communities are dependent upon water availability (i.e., irrigated and rain-fed systems) to produce crops and livestock forage.[9–14]

California's last severe drought, which spanned water years 2012 to 2016, is an important case study of how rangeland livestock producers respond to severe, multiyear drought conditions (Fig. 1).[15] Since 2000, increasingly dry conditions have commonly persisted year-round and exacerbated the seasonal dry period that is characteristic of California's Mediterranean climate; these interacting effects have reduced both forage production and surface water supplies.[12,16] In 2012, conditions deteriorated as co-occurring periods of extremely low precipitation and sustained high temperatures resulted in the driest consecutive 3 years on record (2012-2015).[5] No measurable rainfall was recorded between December 2013 and January 2014 throughout much of California, and the 2015 Sierra Nevada snowpack was 95% below average.[4,5,12] Driven by remarkably arid conditions in 2014, the 2012 to 2016 drought period is currently considered California's worst drought in 1,200 years.[6,17] These unprecedented conditions impacted functioning and productivity of rangeland ecosys-

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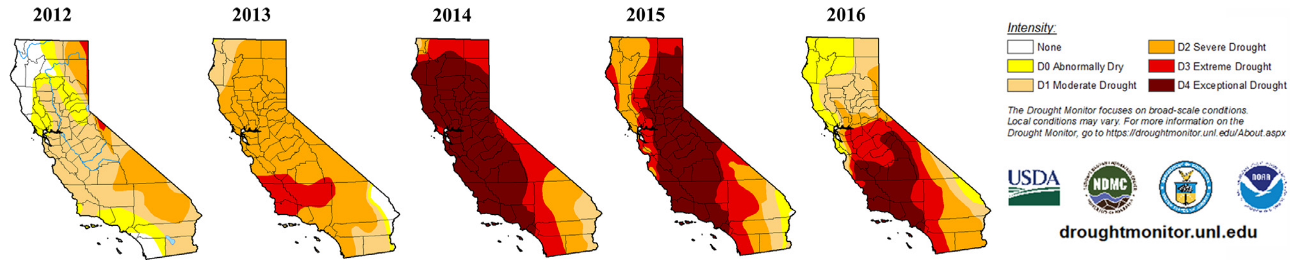

Figure 1. Drought intensity across California at the beginning of each water year, 2012 to 2016.[4]

tems throughout the state, which are almost entirely dependent on seasonal precipitation to support ecosystem services including forage for wildlife and livestock. For example, one California county estimated an 80% loss in forage production across 404,686 hectares (1 million acres) between 2014 and 2015.[12]

As we enter an era of climate uncertainty, supporting rancher and land manager adaptation is arguably the most effective way to facilitate rangeland stewardship.[12–14,18] By preserving working landscapes, ranchers can maintain and enhance critical ecosystem services such as water attenuation, wildlife habitat, and nutrient cycling.[19,20] In addition, the majority of California ranches rely on privately owned rangelands to support their operations; 60% graze on leased private land and 87% graze on private land they own.[21] The interacting threats of climate change-related disturbance (e.g., drought) and land conversion pressure threaten the economic sustainability of ranches; this is evident across the West, where demand for more profitable land uses drives conversion of tens of thousands of rangeland acres each year, with as many as 45% of ranches sold each decade.[22–24] California's historic drought challenged the ability of ranchers to adapt to unprecedented conditions over multiple years while maintaining economic and ecological sustainability of their operations. Building resilience to future droughts in California will rely, in part, on leveraging ranch-tested drought mitigation strategies into future management planning and policy development.[5,12,14]

Here, we examine the effects of California's historic, statewide drought using two separate research efforts: the California Rangeland Decision-Making Survey deployed in 2011 (n = 507) and a series of semistructured interviews (n = 48) conducted in 2016 during the 2012 to 2016 drought. Although these research efforts were meant to be complementary rather than paired, similar questions were posed in the survey and interviews. This facilitated an opportunity to examine drought impacts, drought management decision-making, and outlook on future drought and climate risks before and during the 2012 to 2016 drought. Both the 2011 survey and 2016 interviews are grounded in the Adaptive Decision Making framework, which emphasizes that the sustainability of ranches is dependent on their capacity to adapt to both social and ecological factors.[25] Specifically, we consider whether California's historic drought influenced two critical components of individual adaptive decision-making: 1) management strategies and practices, and 2) management goals and capacity.[25] Our aim is for the information we present to be used to inform place-based, adaptive management and policy approaches for responding to a changing climate.

Methods

Survey and interview instruments

The California Rangeland Decision-Making Survey was sent to producer members (n = 507; 33%) of the California Cattlemen's Association (CCA) between March 2011 and June 2011 (Fig. S1). The survey was administered via a multicontact approach, including both print and online advertisements, and resulted in a 33% response rate.[21,26] In 2016, after 3 years of severe drought, we conducted semistructured interviews with rangeland livestock managers (n = 48) to gather in-depth information on how they were coping with the unprecedented conditions (Fig. S2). Potential interview participants were identified through network sampling of the ranching community in collaboration with the University of California Cooperative Extension, California Cattlemen's Association (CCA), and the California Wool Growers Association (CWGA).[27] This approach does not result in a random sample and is not intended to draw broad inferences. The number of respondents is reported throughout; where n < 48, the question was not applicable to the operation structure of one or more respondents.

Topics were similar between survey and interview instruments (Tables S3-S5). The 2011 survey questions focused on operation and operator demographics, management goals and practices, information resources, and operator values and beliefs.[14] The survey also collected specific data on drought management practices and planning, which provided opportunistic baseline information before California's 2012 to 2016 drought.[12] During the 2016 interviews, we specifically focused on drought impacts, drought management practices, and climate uncertainty and future outlook, in addition to collecting contextual data on operation characteristics. The 2016 interviews were conducted to expand upon the findings of the 2011 survey; in addition to posing the drought management practice questions from the survey, the semistructured interview format facilitated the collection of more in-depth information about rancher motivations behind drought management decision-making. However, as survey responses were anonymous, the comparison between survey and interview re-

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sponses cannot be paired. We do not seek to draw direct comparisons between 2011 and 2016 but rather to examine potential trends useful to preparing for future drought.

Data analysis

Rancher demographics and operation characteristics were summarized using descriptive statistics. Descriptive statistics were also used to report on-ranch drought impacts (percentage of respondents experiencing impacts, mean responses), use and perceived effectiveness of drought practices (percentage of respondents adopting practices, mean responses), and rancher outlook on future drought and climate risks (percentage of respondents agreeing with statements).

Findings and Discussion

Rancher demographics: 2011 survey and 2016 interview participants

The 2011 survey and 2016 interview participants were demographically similar to each other. The median age of survey respondents was 62 (range 25-93; n = 491), and most respondents were men (83%; n = 494). Male interviewees were also the majority (77%, n = 48) with a median age of 61 (range 31-86; n = 48). Notably, there was a greater proportion of women among CWGA member interviewees (CCA interviewees = 5% women; CWGA interviewees = 38% women). In addition, the majority of both survey and interview respondents were from multigenerational ranching families; 71% of survey respondents (n = 493) and 83% of interviewees (n = 48) were second generation or more. Nineteen percent of survey respondents (n = 507) and 17% of interviewees (n = 48) were first-generation ranchers.

Operation size and type was diverse across both 2011 survey and 2016 interview participants. The median operation size for survey respondents was 971 hectares (2,399 acres; range 0-2,059,852 hectares [0-5,090,005 acres]; n = 494). The majority of survey respondents managed cow-calf operations, with a median herd size of 145 head (range 0-8000; n = 494); <10% of respondents grazed sheep, with a mean flock size of 181 head (range 0-8200; median = 0; n = 492). The median operation size of interview respondents was 1,293 hectares (3,195 acres; range 2-60,622 hectares [5-149,800 acres]; n = 48). Interview respondents represented 33 beef cattle enterprises and 28 small ruminant enterprises, with a median cattle herd size of 345 head (range 21-9200; n = 33) and a median sheep flock size of 428 head (range 2-23,470; n = 28). Fifty-four percent of interviewees were members of the CWGA and 46% were members of the CCA (n = 48). For comparison, according to the US Department of Agriculture's most recent Census of Agriculture for California, for beef cattle operators 24% managed <100 cows, 34% managed 100 to 499 cows, and the remaining 42% managed >500 cows or more; for market sheep operators 69% managed <24 sheep, 23% managed 25 to 99 sheep, and the remaining 8% managed >100 sheep.[28]

On-ranch drought impacts

Survey and interview participants reported experiencing increasingly severe drought impacts in both 2011 and 2016, which indicated that drought severity is rapidly escalating for on-the-ground land managers and supports climate model projections.[5,6,29] In 2011, 93% (n = 507) of surveyed ranchers reported they experienced more severe impacts than expected during the most recent drought. In 2016, 81% of interviewed ranchers identified California's historic, statewide drought as the most severe drought they had experienced as a ranch manager (n = 47). Top reported impacts were consistent across survey and interview respondents. The most severe impacts were related to reduced forage availability and income. In 2011, survey respondents reported experiencing drought-related reductions in grazing capacity (77%), profit (55%), and weaning weights (44%) (n = 507) that were more severe than expected. The 2016 interviewees reported reduced forage production and increased expenses as the most commonly experienced impacts for both past droughts (58% and 54%, respectively; n = 48) and the 2012 to 2016 drought (98% and 90%, respectively; n = 48). However, a record high cattle market in 2014 buffered many of the interviewees with cattle operations from drought-related expenses (sheep operations were not buffered).[30] For example, one interviewee stated, "My net income was flat, but revenue was up significantly because of the market,"[i] and others said, "I took extra money from cattle sales and bought hay" and "Cattle prices were high and off-set my expenses."

Interviewed ranchers also rated the severity of impacts on a 1 to 5 scale (1 = slight impact to 5 = severe impact) for the 2012 to 2016 drought. Again, reduced forage production was rated as the most severe impact (3.85; n = 48) and increased expenses were the second most severe impact (3.27; n = 48). These results likely reflect the experience of managing through the 2000 to 2018 megadrought and 2012 to 2016 drought concurrently—many ranchers were coping with regionally dry and drought conditions for more than a decade before 2012, exacerbating drought impacts.[25]

Drought management decision-making

Drought management planning appeared to be consistent between the 2011 survey and 2016 interview efforts; slightly >50% of survey respondents and interviewees reported having a drought management plan in place before the last drought they experienced. In 2011, 56% (n = 452) of surveyed ranchers reported having a drought management plan in place during the last drought they experienced (median date of last perceived drought was 2009). In 2016, 54% (n = 48) of interviewees reported having a drought manage-

[i] Each quote is from a different interviewee and no interviewee was quoted more than once.

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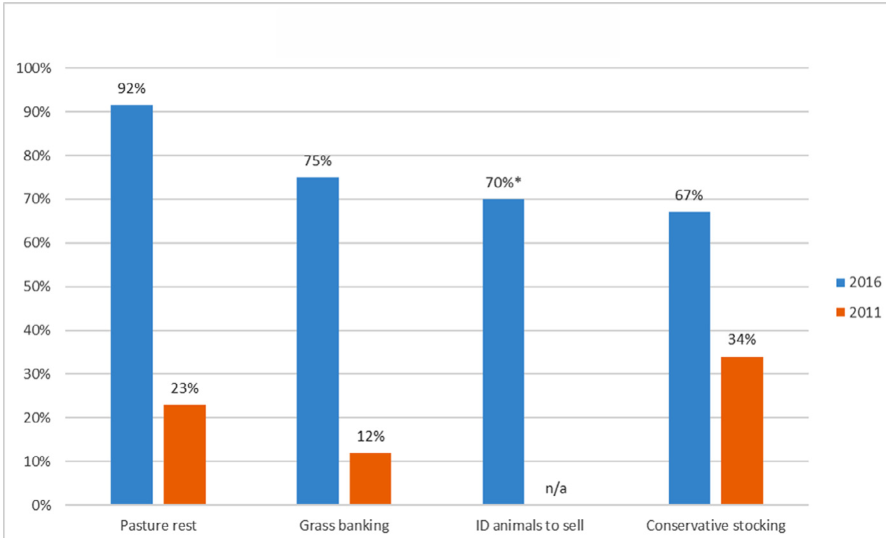

Figure 2. Proactive drought practices used by study participants. Top practices are defined as the four most used practices among interviewees. n = 443 for survey respondents and n = 48 for interviewees unless otherwise noted (*n = 47 as question did not apply to the operation structure of one respondent).

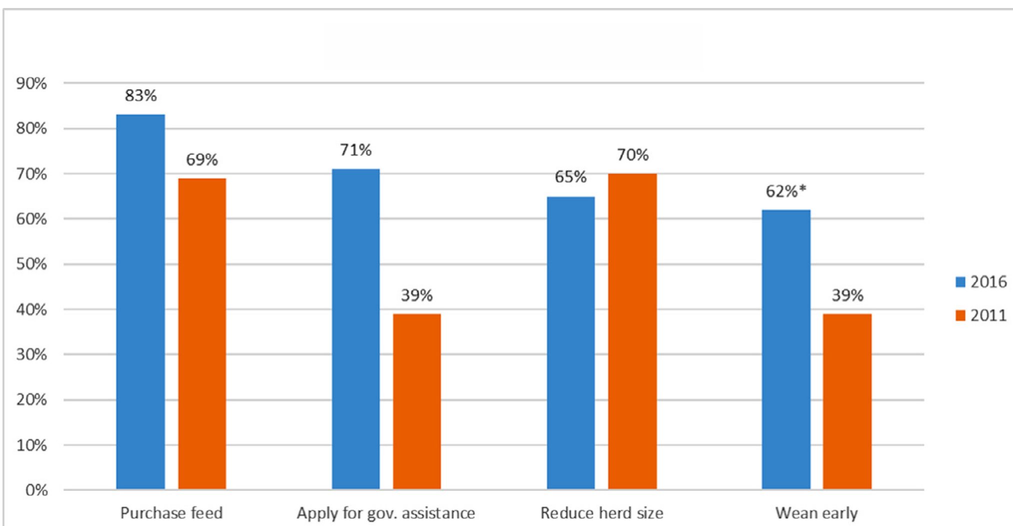

Figure 3. Reactive drought practices used by study participants. Top practices are defined as the four most used practices among interviewees. n = 443 for survey respondents and n = 48 for interviewees unless otherwise noted (*n = 46 as question did not apply to the operation structure of two respondents).

ment plan in place before the statewide drought began in 2012 (CCA = 41%, n = 22; CWGA = 65%, n = 26).

The types of strategies adopted by ranchers participating in the 2011 survey and 2016 interview efforts were very similar. Proactive practices focused on conserving forage and maintaining flexibility, and reactive practices focused on balancing forage supply and demand during drought years (Figs. 2 and 3). However, the average number of drought management practices used per operation increased between 2011 and 2016. Surveyed ranchers (n = 479) reported using an average of one proactive practice and three reactive practices in 2011, whereas interviewed ranchers (n =48) reported using an average of four proactive practices and six reactive practices in 2016. Almost all ranchers reported using at least one reactive drought management practice in both 2011 (99%; n = 443) and 2016 (98%; n = 48), indicating that reactive practices are key to drought management planning, particularly during multiyear, severe droughts. The greater number of reactive practices reported by 2016 interviewees also potentially indicates ranchers were adapting their drought management strategies by adopting a broader range of reactive practices to cope with intensifying drought conditions.

Interestingly, we observed an apparent considerable increase in proactive practice use between 2011 and 2016, both in terms of overall practice use and individual practice adoption. In 2011, 64% (n = 443) of surveyed ranchers reported using forward planning to mitigate drought impacts and in 2016, 98% (n = 48) of interviewed ranchers were currently using at least one proactive practice. Perhaps most notable, there

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was an apparent large increase in the adoption of individual proactive practices in response to the 2012 to 2016 drought. For example: 67% (n = 48) of 2016 interviewees reported using conservative stocking (n = 443), while only 34% (n = 443) of 2011 survey respondents reported using conservative stocking; 92% (n = 48) of 2016 interviewees reported using pasture rest, while only 23% (n = 443) of 2011 survey respondents reported using pasture rest; and 75% (n = 48) of 2016 interviewees reported using grass banking while only 12% (n = 443) of 2011 survey respondents reported using grass banking. The apparent increase in use of proactive practices may indicate underlying drought conditions leading into 2012 were a catalyst for proactive drought planning. It is likely the observed increases in proactive practice adoption between 2011 and 2016, in addition to reactive practice adoption, played a critical role in managing through severe, multiyear drought conditions. During the 2016 interviews, many ranchers confirmed they had continued or enhanced drought preparations and planning. For example, one interviewee stated, "We expect drought every year now – I'm not sure I'd really call it a drought plan. It's just our normal way of ranching now." Other interviewees stated, "My management always takes drought into account" and "Drought will be more influential in our future operation plans because we know now how to prepare better."

Our work, and the work of others, highlights the importance of proactive drought management planning in maximizing flexibility while minimizing tradeoffs.[1,11,12,18,31,32] Proactive practice adoption can be more challenging to invest in and implement due to the unpredictable nature of droughts (i.e., severity, duration, and frequency).[12,32,33,34] The suite of proactive management tools selected by ranchers may also become a driver for the reactive tools available to them during drought. When ranchers have a diversity of responses (i.e., flexibility in management planning) available to address the imbalance of forage supply and demand during drought, they are more likely to reorganize efficiently and remain resilient to drought.[11,12,34,35] In turn, reduced management flexibility increases risk during drought. For example, if pastures have been heavily grazed before drought, a lack of reserved forage will quickly trigger the implementation of potentially costly reactive practices (e.g., purchasing hay or selling livestock). Although proactive strategies (e.g., conservative stocking) still have associated tradeoffs, the tradeoffs associated with reactive strategies can be exacerbated by drought conditions (e.g., cost of hay increasing during drought as resources are restricted and demand increases). As the effects of climate-related disturbance become more frequent, drought must be integrated into all forward management planning to enhance both ranch and range resilience.[11,31,32,36] Therefore, increasing management flexibility via a diversity of both proactive and reactive drought management practices will continue to be a critical component of building ranching and rangeland resilience, particularly during multiyear droughts. Policy could help incentivize and support proactive planning, in addition to the current drought-relief centered government programs.[1,37]

Rancher outlook on future drought and climate risks

It is important to understand how ranchers view future operating conditions when considering research and outreach needs as well as management and policy solutions.[25,38,39] Both the 2011 survey and 2016 interview efforts included the questions: 1) Do you think drought will be more influential in your management plans in the next 10 years than it has been in the past 10 years?; 2) If another drought were to begin right now, how severely would it impact the economic viability of your operation?; and 3) If the frequency of drought increased, would your current management strategies be adequate? We observed clear differences in responses to both questions between 2011 survey respondents and 2016 interviewees, indicating that managing through California's historic drought could have influenced individual perception and planning. For the first question, 43% percent of 2011 survey respondents (n = 465) and 71% of 2016 interviewees (n = 48; CCA = 23%, n = 22; CWGA = 35%, n = 26) reported drought would be more influential in their future management planning. For the second question, 74% (n = 443) of 2011 survey respondents believed future drought would impact their operations "as severely" or "worse" than past droughts, and 58% (n = 47) of 2016 interviewees believed future drought would impact their operations "less severely" than the last (2012-2016) drought. For the third question, 18% (n = 443) of 2011 survey respondents believed their current strategies would be adequate if the frequency of drought increased, and the majority of 2016 interviewees (59%; n = 46) believed their current management strategies would be adequate. Despite this apparent increase in perceived preparedness after managing through the worst of the 2012 to 2016 drought, interviewees also pointed to the emotional distress it caused. For example, one interviewee stated, "I fed hay every day for 14 months. I am mentally and physically tired," and other interviewees stated, "If another drought were to start now, then we would probably sell out. The stress would be too much" and "I will be scarred by this experience."

These responses suggest drought experience impacted individual perceptions of threat and preparedness in two distinct, and seemingly opposing, ways. Ranch managers believed: 1) drought will be more influential in their future management planning and; 2) their current management strategies would be adequate to mitigate future drought impacts. This second outcome may be a combination of feeling more prepared to manage through future severe, multiyear conditions due to increased management capacity (i.e., increased adoption of drought management strategies, specifically proactive practices) and a perception that the 2012 to 2016 drought was so severe it was difficult to imagine worse future conditions. One surveyed producer commented, "This drought has been as bad as any I've experienced - I can't imagine one much worse." It is difficult to draw a single conclusion about what may be driving these two outcomes, particularly since increased perception of drought-related threats can be both a motivator and a deterrent for forward plan-

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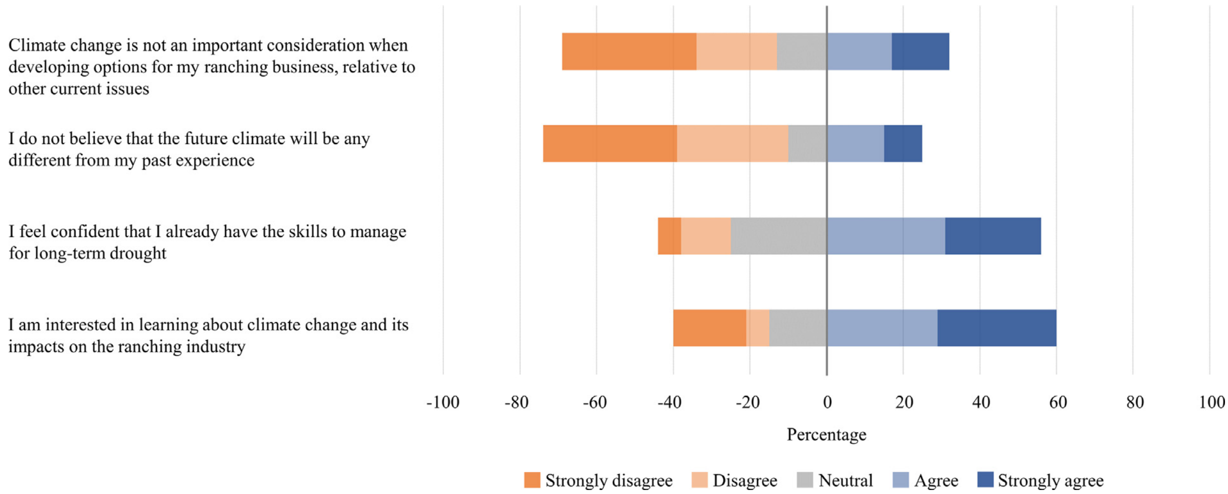

Figure 4. Summary of 2016 interviewee responses to statements regarding climate change and implications for management. Statements were adopted from Marshall et al.[41]

ning.[40,41] This suggests that drought support should be tailored to the needs of individual ranchers. Ranchers likely developed new skills and insights as they managed through California's 2012 to 2016 drought; however, it is also likely drought conditions will be as severe, if not more so, in the future.[6] Indeed, the current 2020 to 2021 drought is considered the "new historic" drought. Technical and policy support for science-based decision-making will be critical to buffering the "whip-lash" of responding to a drought crisis, deferring further planning efforts during periods of adequate water resources, and then facing another, potentially more severe disaster. Leveraging lessons learned from past droughts into forward planning for the next drought will be key in building social-ecological resilience to these complex natural hazards. As one rancher stated, "I'm always planning ahead, preparing, looking long-term, and looking ahead to disaster."

Increasing opportunities for ranchers to assess long-term planning horizons and anticipate possible changes can help them more effectively address future challenges.[25] Previous work has revealed outlook on operation longevity can impact individual decision-making, in particular; perceived consequences of risk influence decision-making and practice adoption.[25,38,39] Therefore, examining rancher outlook on future climate conditions may offer valuable insights into their drought management decision-making. To evaluate changes in operator planning horizons, we asked the 2016 interviewees about their outlook for future droughts as well as their level of agreement (1 = "strongly disagree" to 5 = "strongly agree") with a series of statements regarding climate change and implications for management (Fig. 4). Statements on future climate change impacts and implications for management were adopted from interviews conducted with Australian graziers after the country's Millennium Drought: 1) "Climate change is not an important consideration when developing options for my ranching business, relative to other current issues"; 2) "I do not believe that the future climate will be any different from my past experience"; 3) "I feel confident that I already have the skills to manage for long-term drought"; and 4) "I am interested in learning about climate change and its impacts on the ranching industry."[42]

On average, interviewed ranchers disagreed with the strong negative statement about importance of climate change for their ranching business (2.54 mean rating for climate change question 1; n = 48; CCA = 2.50; CWGA = 2.58), suggesting they view climate change as an important factor in their operation planning. Interviewees also expressed the perspective that future climate would be different from their past experiences (2.35 mean rating for climate change question 2, n = 48; CCA = 2.77, CWGA = 2.00). Interviewees indicated they were moderately confident in their skills to manage for long-term drought (3.56 mean rating for climate change question 3, n = 48; CCA = 3.91, CWGA = 3.27), and were also moderately interested in learning more about climate change and its impacts on the ranching industry (3.48 mean rating for climate change question 4, n = 48; CCA = 2.91, CWGA = 3.96). Overall, it appears that ranchers are interested in future climate conditions and believe the future climate will be different. These results have landscape-level implications, as on-the-ground decision-makers will play critical roles in future management and policy actions for climate change mitigation and adaptation.[42,43]

Limitations

Limitations are centered around the fact that the 2011 surveys and 2016 interviews were not designed to be paired. For example, survey respondents were offered fewer practices to select from than interviewees. However, we still saw greater adoption of the practices included in both the survey and the interview questions.

Conclusions

Drought is a complex natural hazard with multiscale impacts; however, the effects of these impacts are ranch-specific,

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and both ranch and rangeland resilience must be prioritized concurrently to mitigate the negative impacts of drought on working landscapes.[11,12,14,43] Therefore, effective drought mitigation will require coordination at ranch, community, and policy levels. At the ranch level, our results emphasize the importance of having a diverse portfolio of both proactive and reactive drought management practices to cope with drought. As just over one-half of surveyed and interviewed ranchers reported having a drought plan in place, there is a substantial opportunity to increase preparedness by aiding ranchers in developing drought management plans. Additionally, decision-support tools to help ranchers match their preferred proactive strategies with cost-effective, operation-specific reactive strategies may help increase the use of science-based decision-making during drought. Future research efforts should focus on the effectiveness of proactive strategies and drivers of proactive practice adoption, as these strategies may reduce both risks and tradeoffs associated with drought mitigation.

At the community level, building trusted relationships between ranchers and support organizations will likely be an effective and important way to support rancher and rangeland resilience to climate change.[14,31,42] We found that California ranchers are already increasingly considering drought in their future management planning, adopting more strategies to cope with drought, and are expecting the future climate to be different—supporting this "drought-planning mentality" further through research and outreach efforts may be the next step in developing effective drought mitigation strategies.[37] Support organizations can remove the burden of organizing post-drought lessons learned by working with ranchers to examine successful drought management strategies further through applied research and outreach programming. For example, outreach events that provide ranchers with operation-specific information about the economics of drought decision-making can encourage drought plan development and proactive practice adoption. In addition, during the 2012 to 2016 drought ranchers noted the ability to problem solve and talk through new ideas with other peer ranchers was key. Support organizations can facilitate these opportunities.[12] As support organizations are engaged with the ranching community throughout the country, these findings are broadly applicable.

At the policy level, our work adds to the research emphasizing drought plans are not "one size fits all" and policy must be designed to support drought adaptation and mitigation strategies at the ranch level; drought plans and support programs must be tailored to individual needs.[11,12,14,32,34,39,44] Supporting individual drought planning efforts to prioritize management flexibility will be key in promoting both ranch and rangeland resilience to drought. The unique characteristics of ranching communities often create regional differences in drought planning and response; these social ecological systems have many significant factors shaping their functionality.[14,25] For example, managing through the severe conditions of the 2012 to 2016 drought appears to have made drought a greater management planning priority for ranchers and increased their perceived preparedness for the next drought. Research in other western states has found similar results, but also observed different drivers (i.e., specific drought impacts) and changes that are likely unique to those production systems.[11,31] As severe, multiyear droughts continue to unfold throughout the West, researching these regional differences will be important to help attune policy to fit local need.

Declaration of Competing Interest

L.M. Roche serves on the Steering Committee for *Rangelands* but had no editorial influence on the review or publication of this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rala.2021.10.003.

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