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Producer Preferences for Drought Management Strategies in the Arid West

By

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Abstract

This study uses choice experiments to assess fresh produce and hay/forage grower preferred drought management strategies, the level of drought at which growers adopt specific management strategies, and the level of drought at which they choose to exit farming in the arid West. Results show preferred strategies differ by drought level and across grower groups. Using logit models, we find that fresh produce growers prefer adopting a water-saving technology (cover crops, manure/mulch application, etc.) and hay/forage growers prefer switching to a more efficient irrigation system. Growers would only exit farming in extreme circumstances such as loss of all water resources. Policies aimed at assisting growers with drought adaptation should focus on preferred strategies to ensure effectiveness. Incentives to offset adoption costs are also recommended. Additionally, growers may benefit from information related to productivity changes under various drought management strategies and drought scenarios.

Key words: agricultural production, choice experiments, drought management strategies, logit models, arid west

Introduction

Agricultural production is the largest user of water resources in the U.S., responsible for approximately 80% of all consumptive water use (USDA ERS, 2019). Irrigated crops and livestock production alone account for 37% of total water withdrawals (Dieter et al., 2018). Agricultural sectors, especially those using non-irrigated production systems which rely on rainfall, are among the first impacted by drought (Freire-González et al., 2017). Previous studies confirm the serious negative impacts of drought on agriculture such as reduced yields and crop damage, smaller and lower quality produce, and increased vulnerability to pests, all of which result in large economic losses and profitability for growers (Lobell et al., 2006; Schlenker and Roberts, 2009; Hatfield et al., 2011; Fisher et al., 2012; Kuwayama et al. 2018). Hence, persistent drought has severe economic consequences, especially for agriculture dependent rural communities (Lal et al., 2012; Howitt et al., 2017).

However, previous studies have illustrated that U.S. agricultural producers readily adopt water conservation strategies in response to drought, including but not limited to fallowing land with low-value crops, pumping groundwater (Zilberman et al., 2002), as well as implementing conservation tillage (Ding et al., 2009) and drought-tolerant varieties (McFadden et al., 2018) Drought is especially problematic in arid and semi-arid regions in the western U.S where water is already a scarce commodity. Hence, in this study, we examine producer preferred drought management strategies in the southwest U.S., specifically Utah. Utah is currently the third driest state in the U.S. in terms of mean annual precipitation (NOAA, 2020) and 65% of the state experienced abnormally dry conditions or worse from 2000-2019 (NIDIS, 2019a). In 2018-2019, 51% of the state suffered moderate to severe drought (NIDIS, 2019b). This level of drought damages pastures and crops and leads to economic losses in agriculture. In addition, water shortages are common at this level of drought, especially late in the summer, and water restrictions are often imposed. Since agricultural production and food processing are among Utah's major industries contributing 2% to state GDP (BEA, 2019), adapting to drought and maintaining agricultural production is important to the Utah economy.

Hay/forage and fresh produce are among the primary agricultural commodities in terms of sales in Utah. Hay/forage, a high water-use crop and a primary feed source for livestock, generated $182 million in sales in Utah in 2017 (UDAF, 2018), not including the value of hay grown and used within the same operation. Fresh produce is a high value crop and is very important to the Utah economy, especially on the Wasatch Front with $56 million in sales annually (USDA NASS, 2017). Fresh produce is grown on smaller farms (<100 acres) that often use water conserving irrigation systems.

Production of hay/forage and fresh produce differ in their water resource needs and likely face distinct challenges in the presence of drought. In this study we examine preferred drought management strategies for each grower group, assess grower willingness to adopt a particular strategy among differing drought scenarios, and under what drought conditions they would prefer to exit farming altogether. Our primary research question is whether drought severity impacts grower preferred drought management strategies. To elicit grower drought management preferences, we employed choice experiments conducted at grower meetings and through online surveys. Study findings may be used to inform local, state and federal policy aimed at improving the ability of agricultural producers to adapt to or mitigate the negative effects of drought.

Background and Literature Review

Drought is considered to be one of the indicators of the climate change (U.S. Environmental Protection Agency, 2016), and past studies have provided evidence of the negative impacts of both drought and climate change on the agricultural sector (e.g. Lobell et al., 2006; Schlenker and Roberts, 2009; Hatfield et al., 2011; Fisher et al., 2012; Kuwayama et al. 2018). Previous studies found that U.S. producers do implement mitigation and adaptation measures in response to drought and climate change. These measures include adoption of water conservation technologies and techniques such as fallowing land and pumping groundwater in California (Zilberman et al., 2002); conservation tillage among crop growers in Iowa, Nebraska, and South Dakota (Ding et al., 2009); growing drought-tolerant varieties corn production (McFadden et al., 2018); as well as aquifer pumping and using low water-use crops in the Upper Rio Grande Basin (Ward, 2014). Producers in Nebraska, ranging from small specialty crop producers to commercial farm operations, applied organic soil enhancement and selected drought-tolerant crops frequently to reduce the effects of drought (Knutson et al., 2011). Several studies examined actions taken by livestock producers in Wyoming, South Dakota and Nebraska in response to drought, finding that purchasing additional feed and herd reduction were among the top three preferred strategies (Bastian et al., 2006; Kachergis et al., 2014; Haigh et al., 2019a).

Previous studies highlight the benefits and importance of grower adaptation and mitigation to drought and climate change. Malcolm et al. (2012) showed that adaptation measures (adjustment to crop rotations, tillage practices, and land allocation decisions) under different climate change scenarios resulted in higher net returns for field crop growers in regions outside the Corn Belt when compared to no adaptation, and even higher net returns when drought-tolerant varieties were available. Burke and Emerick (2016) estimated that if the ability of U.S. corn producers to adapt to extreme heat remains unchanged, annual corn yields will decline by 15% by 2050, indicating that more aggressive adaptation measures are needed to ensure food security. However, past studies also found that producers tend to adopt measures only after having a personal experience with drought or extreme weather events, i.e. their measures are reactive rather than preventative (Wreford and Adger, 2010; Rey et al., 2017; Lane et al., 2018).

The benefits and importance of the adaptation and mitigation measures, as well as producers' reactive approach to adopting the measures, point to the need to better understand the determinants of their decisions to adopt drought management strategies, which can inform policies aimed at supporting and promoting agriculture resilience to drought and climate change. In the U.S., several studies examined factors that affect farmers' decisions to adapt to climate change and drought in general and their choices of specific adaptation and mitigation strategies (e.g. Haden et al., 2012; Mase et al., 2017; Morton et al., 2017; Castellano and Moroney, 2018; Roesch-McNally, 2018). The examined factors include producer-specific factors, e.g. producer beliefs, values, attitudes, and farm characteristics; climatic and weather factors, which directly affect yields, total output and quality; as well as other factors in the external environment, which can affect the producer indirectly, e.g. government assistance and market conditions.

Producers' perceptions that climate change is a real threat and/or specific concerns about drought are positively associated with interest in adopting the mitigation and adaptation actions (Haden et al., 2012; Arbuckle et al., 2013) and actual implementation (Mase et al. 2017). Wheeler et al. (2013) found that Australian farmers, who believe in climate change, are more likely to change their crop mix and adopt a more efficient irrigation system. Actual experience with drought positively impacted decisions of Midwest farmers to adopt drought management measures (Morton et al., 2017) and improved perceived drought preparedness among Utah ranchers (Coppock, 2011). In addition, Negri et al. (2005) found that a change towards more extreme temperature and precipitation values played a critical role in the decision to adopt irrigation among U.S. corn, soybean and cotton growers, but other factors, including water availability, farm size, soil conditions and operator demographics, also played a role. Delayed or lack of plant emergence or growth, decreased forage production, and/or deteriorated range conditions, observed by livestock producers, positively affected likelihood of adopting drought-coping measures (Haigh et al., 2019b). Haden et al. (2012) found that producers in California preferred drought management measures with short-term benefits rather than long-term benefits. Ease of adoption and upfront costs impacted producer preferences as well. In another study, Annan and Schlenker (2015) found that crop insurance and government programs reduced producers' motivations to adopt costly adaptation measures.

Additional studies have specifically used choice experiments to elicit producer acceptance of policies aimed at increasing water supply reliability in Spain (Alcon et al., 2014) and producer preferences for drought response policies in Canada (Conrad et al., 2017). Other recent studies employed choice experiments to examine producer preferences for drought-tolerant traits in rice and weather-indexed insurance in India (Ward and Makhija, 2018; Arora et al., 2019), Bangladesh (Ortega et al., 2019), Sri Lanka (Prasada, 2020), and Ireland (Doherty et al., 2021). However, to our knowledge there are no current studies employing choice experiments to examine grower sensitivity to reductions in yield or productivity resulting from drought, or more specifically, how changes in yield impact grower preferences for drought management strategies. The purpose of this study is to fill this gap and build on early results (Curtis et al., 2020), while focusing on several grower groups in drought-prone Utah and surrounding states. Our aim is to understand whether differences in drought severity, indicated by various levels of yield, influence the choice of drought management strategies, or whether there are strategies which are consistently preferred by growers, regardless of drought severity. We also examine whether there are differences in preferences among grower subgroups based on selected grower characteristics. Understanding grower preferred drought management strategies and whether their preferences change depending on drought severity is important when designing policies aimed at assisting agricultural producers in managing or adapting to drought.

Data Overview

The data for the study were collected through in-person and online choice experiments accompanied by a survey at grower meetings and online in 2019. Data were collected separately for fresh produce growers (N=20) and hay/forage growers (N=35). Field lab experiments were held at commodity/producer meetings and participants were recruited through an invitation to attend the lab experiment and workshop following the experiment. Participants were not paid to participate. Additional choice experiments were conducted via online surveys. Participants were recruited through emails to grower organization members and Extension list serves. Again, no incentive or fee was provided to participants. Of those study participants who indicated their farm location, the majority were residents of Utah (94%), and the remainder were from Idaho (4%) and Arizona (2%), i.e. nearby states with similar growing conditions to Utah. Table 1 provides an overview of characteristics for each grower group.

[Insert Table 1 here]

The majority of the sampled fresh produce growers farm on less than 10 acres of land (84%), grow vegetables as their primary crop (85%), and use drip irrigation (75%). Many of them have used water saving technologies in the past, such as mulch applications (80%), wind breaks (55%) and cover crops (55%). The largest share of hay/forage growers manage between 101 and 300 acres of cropland (37%), hay is their primary crop (46%), and they use wheel line irrigation (43%). Also, the majority of them have used cover crops (67%) and manure applications (82%), which are water saving technologies. For example, manure applications can improve water use efficiency by significantly increasing soil water storage (Wang et al., 2016). Across these two grower groups, there is a slightly higher share of males in the fresh produce group (53%), while males prevail among hay/forage growers (91%). In both groups, direct sales outlets were heavily used (65% to 70%).

Methods

Choice experiments were employed to examine how reductions in the percentage of crop harvested (yield), as a result of drought, affected grower preferences for drought management strategies. Fresh produce and hay/forage growers were told that drought could result in a large percentage of crop loss, and then were asked whether they would adopt a particular strategy (= 1 if yes, = 0 if not) if it would result in a specific minimum percentage of crop harvested, 40%, 60%, and 80% across three different strategies (see choice tasks provided to fresh produce growers in the Appendix). The order in which the percentage of crop harvested for each strategy was presented to respondents was random. In total, growers answered nine choice questions and the offered strategies somewhat varied across grower groups due to differences in production systems. For fresh produce growers, the strategies included "adopt a water-saving technology" such as cover crops, mulch applications, and wind breaks, "switch to a drought-resistant variety", and "sacrifice lower value crops." For hay/forage growers the strategies included "switch to a more water efficient irrigation system," "adopt a water-saving technology" such as low/zero till, cover crop, or manure application, and "switch to low water-use crop/variety."

The utility of grower *n* from choosing strategy *i* in choice scenario *t* is (Train, 2009)

$$U_{nit} = \alpha_i + \beta_i X_t + \varepsilon_{nit}, \qquad (1)$$

where X_t is the minimum percentage of crop harvested in choice scenario t, β_i represents marginal effect of X_t on the utility, α_i is alternative-specific constant which represents effect of unobserved factors associated with strategy *i* on the utility, and ε_{nit} is i.i.d. type I extreme value. Coefficients α_i and β_i are strategy-specific, which is denoted by the subscript *i*. A rational grower will choose strategy *i* if it provides higher utility compared to the alternative of not choosing the strategy. The probability that grower *n* choses strategy i from among alternatives $J = 2$ in choice scenario *t* is calculated as (Train, 2009)

$$P_{nit} = \frac{\exp\left(\alpha_i + \beta_i X_t\right)}{\sum_{j=1}^{J} \exp(\alpha_j + \beta_j X_t)}. \qquad (2)$$

The analysis for each grower group was completed using binary logit models, estimated using penalized maximum likelihood (PML) estimation procedure instead of the traditional maximum likelihood (ML) procedure. We choose the PML approach due to study small sample sizes. Firth (1993) proposed PML estimation for the reduction of small sample bias in maximum likelihood estimates of generalized linear models, and Heinze and Schemper (2002) examined this approach further in the context of a logistic regression, identifying additional advantages of this method. Using simulation, Kessels et al. (2019) showed that Firth's approach reduces the bias and variance of multinomial logit model estimates compared to the traditional ML approach. They concluded that PML approach is particularly useful in smaller samples of 24 respondents or less, and PML estimates converge to ML estimates with larger samples. Similarly, Rainey and McCaskey (2015) showed that PML approach improves ML estimates of logit models by reducing the variance and bias, particularly in smaller samples of around 50 observations. PML approach to obtaining estimates of logistic regression has been applied for example in Sargeant and Mann (2009) and Kupfer et al. (2016).

We hypothesize that the increase in the percentage of crop harvested will increase the utility and willingness to adopt strategy *i* relative to not adopting the strategy. However, there are other factors that affect the willingness to adopt a strategy (e.g. time spent learning new practices, monetary cost of adopting new practices, etc.), and their effect is captured in constant α_i. We can calculate the percentage of crop harvested at which the grower is indifferent between adopting and not adopting strategy *i* as

$$WTA_i = -\frac{\alpha_i}{\beta_i} * 100\%. \qquad (3)$$

This represents the minimum percentage of crop harvested at which the grower is willing to adopt strategy *i* instead of not adopting (and risking suffering larger crop losses under the current management practices), thus we consider it to be a measure of the "willingness to adopt" (WTA). It is important to note that lower WTA_i value means higher willingness to adopt. We can also compare the minimum needed percentage of crop harvested for different strategies to examine growers' preferences for the strategies: if $WTA_i < WTA_j$ for strategies *i, j*, the strategy *i* is said to be preferred over strategy *j*, because grower is willing to adopt strategy *i* at lower percentage of crop harvested than needed to adopt strategy *j*. Krinsky and Robb (1986) method with 10,000 replications is used to determine significance of the calculated values.

We are also interested in examining the effect of various grower-specific characteristics on the willingness to adopt a strategy *i* relative to not adopting this strategy. The characteristics that are examined and their categories are listed in Table 1. For a characteristic with *M* categories, one category needs to be left out so that the model can be identified and the vector of the remaining $M - 1$ categories with corresponding $\gamma_{i,m-1}$ coefficients, estimated for strategy *i,* is added to equation (1). In this case, the constant α_i in equation (1) will absorb the effect of the unaccounted factors for the category which is left out and the $\gamma_{i,m-1}$ coefficients will capture the differences in the utility relative to this category. Then, WTA_i in equation (3) represents the minimum percentage of crop harvested (at which the grower is willing to adopt strategy i), specifically for the category which is left out from the model.

In addition to the choice experiments, we also asked growers directly which one of the offered drought management strategies they preferred most to avoid a large loss of crop, not specifying the percentage of crop harvested. And finally, we asked them in an open-ended question under what drought circumstances they would prefer to exit farming all together.

Results

Tables 2 and 3 report the results of the logit models. For each grower group, the strategies offered are in the first row and they follow in the order of preference from the most preferred (1) to the least preferred (3), based on the calculated WTA_i values. Fresh produce growers (Table 2) are the most willing to adopt a new water-saving technology, followed by switching to a drought-resistant variety and sacrificing lower value crops. The minimum calculated percentage of crop harvested (WTA) for adopting a water-saving technology is 36%, which means that fresh produce growers would be willing to adopt the technology if they can harvest at least 36% of their crop. Willingness to switch to a drought-resistant variety and sacrifice lower value crops is 53% and 57% of crop harvested, respectively. Hay/forage growers (Table 3) prefer to switch to a more efficient irrigation system (minimum 39% of crop harvested) than to adopt a water-saving technology (47%) or switch to a low water-use crop (50%).

[Insert Tables 2-3 here]

The results discussed so far were obtained analyzing responses to the choice sets, used to understand how grower preferences for the offered strategies change depending on the percentage of crop harvested. Growers evaluated each strategy individually and at varying levels of crop harvested. In addition, we asked growers to select their most preferred strategy to avoid significant crop losses. We asked this question to compare their drought management strategy preferences with and without different levels of drought or resulting crop losses. Table 4 summarizes shares of growers selecting each strategy as their most preferred.

[Insert Table 4 here]

First, “moving out of farming” is selected as most preferred by a relatively small group of respondents, ranging between 0% (fresh produce growers) and 15% (hay growers). “Adoption of a water saving technology” is the most preferred strategy among fresh produce growers (40% share), which is in line with the findings based on the logit models. But for the remaining strategies, growers’ preferences are somewhat different depending on whether they are given the information on the minimum percentage of crop harvested and whether they are evaluating the strategies directly against each other. Switching to a drought resistant crop requires more effort than sacrificing lower-value crops, which is the more preferred strategy when the crop harvested is not considered, but fresh produce growers are more willing to change to a drought resistant crop at lower levels of harvested crop. Similarly, when hay growers are not provided information on the harvested crop, they prefer to switch to a low water-use crop than a water efficient irrigation system; however, the logit models found that at lower levels of harvested crop the order of the preferences changes. In summary, the results indicate that considering a specific percentage of crop harvested affects growers’ preferences, which suggests that it is an important piece of information when choosing an adaptation strategy and can influence preferences among a set of options.

Additionally, we asked growers what percentage of crop loss they consider large to examine whether there is a relationship between their perceptions and their most preferred drought management strategy, i.e. whether the preferences for the strategies differ depending on grower sensitivity to crop loss. However, the Fisher's exact test did not reveal evidence of a relationship between the choice of the most preferred strategy and percentage of crop loss considered large (p-value = 0.914 for fresh produce growers, p-value = 0.731 for hay growers).

We also asked growers to describe in their own words under which drought circumstances they would stop farming. Out of 16 responses received from fresh produce growers, 44% would no longer grow fresh produce if there was no water at all, 38% mentioned high water cost (which would likely be the case in the event of drought), 19% mentioned not enough water, and 13% would not stop growing fresh produce under any circumstances. Among hay growers, 26% of 23 respondents mentioned issues with profitability, production, or market (potentially as a result of drought), 26% mentioned no water, 17% mentioned multiple year drought/extreme weather conditions, and 9% gave no reason. Growers seem to interpret drought conditions in terms of the impacts or consequences for their operation and ability to continue farming rather than some specific weather conditions. Also, grower responses indicate that it would take a lot for them to move out of farming and some would continue farming regardless of the drought conditions.

Impact of grower characteristics on preferences for strategies

Table 5 reports estimated WTA values (i.e. minimum percentage of crop harvested required to adopt a strategy) for subgroups of fresh produce growers, showing the effect of selected factors on the willingness to adopt the strategies and the differences across the subgroups. First, considering the most preferred strategy among fresh produce growers—adopt a water-saving technology—we find statistically significant difference in WTA values only between those who primarily use drip irrigation (42% of harvested crop needed) and those who use other irrigation systems (15% of harvested crop needed, but statistically insignificant); those who use drip irrigation are less willing to adopt new water-saving technologies.

[Insert Table 5 here]

When considering the strategy to switch to a drought-resistant variety, males are less willing to do so than females (62% of harvested crop needed vs. 39%), and so are those who farm on more than 10 acres (82%) compared to those who farm on 10 acres or less (49%). Also, those who grow another crop as a primary crop (81%) are less willing to adopt this strategy than those who grow vegetables (49%). Finally, those who have not used mulch applications (73%) before are less willing to switch to a drought-resistant variety than those who have used these practices (49%).

Looking at preferences for the least preferred strategy—sacrifice lower value crops—those who us an irrigation system other than drip are significantly more willing to adopt this strategy (45%) than those who use drip (61%). Further, those who have used wind breaks before are more willing to adopt this strategy (51%) over those who have not (63%). On the other hand, those who have not used cover crops before are more willing to adopt this strategy (49%) than those who have (63%).

Table 6 reports results of the analysis done for the subgroups of hay/forage growers. First, the most preferred strategy among hay growers—switch to a more efficient irrigation system—is significantly less preferred by those who farm on 101-300 acres (56%) than those farming on 100 acres or less and between 301-1000 acres, and by those who primarily grow hay (54%) compared to those who primarily raise livestock. It is also less preferred by those who use flood as their primary irrigation system (72%) compared to those who use pivot (38%) and wheel line, and those who have used manure applications before (47%) compared to those who have not. On the other hand, adoption of a water-saving technology is preferred more by those who farm on 101-300 acres (35%) than those farming on 100 acres or less (54%) and between 301-1000 acres (58%). But as with the previous strategy, this strategy is also less preferred by those who grow hay (54%) compared to those who raise livestock (39%).

[Insert Table 6 here]

Looking at the least preferred strategy among the offered strategies—switch to a low water-use crop/variety—females are significantly more willing to adopt this strategy than males (52%), and those who don't primarily use direct sales (41%) more than those who use direct sales (57%). Further, hay growers farming on over 1000 acres are significantly more willing to adopt this strategy compared to those farming on 301-1000 acres (54%). Also, those who primarily use wheel line irrigation (45%) are more willing to adopt a low water-use crop compared to those using flood irrigation (64%), and those who have not used manure applications before compared to those who have (55%).

Summary and Conclusions

In this study, we examined preferred drought management strategies among fresh produce and hay/forage growers, operating primarily in drought-prone Utah. The data were collected using choice experiments at grower meetings and online in 2019 and were analyzed using PML models. The main objective of the study was to identify grower preferred drought management strategies, examine how preferences change under several drought scenarios, and under what conditions growers would choose to exit farming. Drought scenarios were represented by varying the percentage of crop harvested. Although impacts of a variety of factors on the choice of drought management strategies among agricultural producers were examined in previous studies, including climatic and weather factors indicating drought (e.g. Negri et al., 2005; Haigh et al., 2019b), to our knowledge this is the first study that has examined the impact of changes in yields, while using choice experiments and engaging different groups of growers.

We find that fresh produce and hay/forage growers are sensitive to the percentage of crop harvested (yields) under drought conditions, since it influenced their decision to adopt each of the examined drought management strategies. But the decision to adopt under a specific drought level varies across the strategies, and there are also differences between the two grower groups in terms of the most preferred strategy. Fresh produce growers prefer to adopt a water-saving technology, while hay/forage growers prefer most to switch to a more efficient irrigation system.

They are willing to adopt these strategies if they harvest at least 36% and 39% of crop, respectively, which would indicate a severe drought. However, when no information about the degree of crop harvested (yield) is provided, the most preferred strategy among hay/forage growers is to switch to a low water-use crop/variety. This indicates that information about drought severity and associated minimum yields under each strategy, are critical pieces of information in the decision-making process.

The analysis completed by grower subgroups provided additional insights into factors affecting preferences for drought management strategies. Among fresh produce and hay/forage growers, gender of the primary operator, acres farmed, type of primary crop, type of irrigation system used, as well as application of sustainable practices (manure, etc.) somewhat influences preferences for one or more of the examined strategies, but not necessarily in the same way across the grower groups even for similar strategies. For example, growing perennial crops such as fruit trees among fresh produce growers and alfalfa among hay growers reduced willingness to switch to more water-efficient crops/varieties, as expected given the heavy cost of taking out perennial crops with long lifespans. Also, previous application of sustainable practices reduced willingness to switch to more water-efficient crops/varieties among hay/forage growers but increased for fresh produce growers. Further, the type of irrigation system primarily used affects willingness to adopt a water-saving technology among fresh produce growers, but not among hay/forage growers. This illustrates that some factors may affect preferences differently across grower groups even for similar drought management strategies, which further emphasizes the need to examine preferences by producer/grower groups.

Overall, we find that the drought would have to be very serious and long-term for producers to exit farming/ranching in general, but the choice of preferred strategy varied among the two grower groups examined here. Thus, policies aimed at improving grower uptake of drought management strategies need to be commodity-specific and target grower preferred options to increase the likelihood of success. Policies which provide incentives such as covering a portion of the costs of drought management strategy implementation are also recommended. Ward et al. (2014) found that subsidies motivated farmers to adopt more efficient irrigation systems, which played an important role in offsetting negative impacts of drought on farm income and increasing the value of food production. Currently, there are a few programs in place, such as the Natural Resource Conservation Service (NRCS) EQIP program, that provide funding to support grower implementation of water conservation practices, including more efficient irrigation systems. The costs associated with each drought management strategy examined in this study are different and thus need to be identified. However, policy makers also need to consider the "rebound-effect," i.e. the possibility that a switch to a better water management system for agricultural production, such as more efficient irrigation technology, may lead paradoxically to overall higher water consumption (Pfeiffer and Lin, 2014).

Water pricing is another instrument that can be implemented to manage water use. Farmers consider adoption of more efficient irrigation systems and higher-value crops in response to higher water prices, but again subsidies and incentives were found necessary to reduce the capital and risk constraints (Molle et al., 2008) and motivate the adoption. In other words, higher water pricing should be implemented carefully and as a complement to subsidies. Finally, crop productivity, which can be achieved under the various drought management strategies during different levels of drought, should be investigated and the information should be provided to producers where available. Future work should also examine the applicability of study results to other regions and crop types.

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Table 1. Sample summary statistics for grower characteristics

Characteristic	Fresh Produce Growers		Hay/Forage Growers	
	Category	Count; % share	Category	Count; % share
Gender of the primary operator	Male	10; 53%	Male	32; 91%
	Female	9; 47%	Female	3; 9%
Primary sales outlet	Direct	14; 70%	Direct	22; 65%
	Direct & wholesale	5; 25%	Wholesale	11; 32%
	Other	1; 5%	Other	1; 3%
Acres farmed	<=10	16; 84%	0-100	12; 34%
	11-25	1; 5%	101-300	13; 37%
	26-100	0; 0%	301-1000	5; 14%
	>100	2; 11%	>1000	5; 14%
Primary crop/ livestock type	Vegetables	17; 85%	Hay	16; 46%
	Tree fruit	2; 10%	Livestock	14; 40%
	Other	1; 5%	Other	5; 14%
Irrigation system used primarily	Flood	2; 10%	Flood	6; 17%
	Pivot	1; 5%	Pivot	14; 40%
	Drip	15; 75%	Wheel	15; 43%
	Other	2; 10%		
Mulch applications used before	Yes	16; 80%	-	
	No	4; 20%		
Wind breaks used before	Yes	11; 55%	-	
	No	9; 45%		

Cover crops used before	Yes No	11; 55% 9; 45%	Yes No	22; 67% 11; 33%
Manure applications used before	-		Yes No	28; 82% 6; 18%
Specify what is a large % of crop loss/grazing efficiency reduction to you	100% 80-99% 60-79% 40-59% 20-39% <20%	0; 0% 0; 0% 2; 10% 10; 50% 6; 30% 2; 10%	100% 80-99% 60-79% 40-59% 20-39% <20%	0; 0% 2; 6% 12; 35% 10; 29% 9; 26% 1; 3%
N (all respondents)		20		35

Table 2. PML model results for fresh produce growers

Strategy	(1) Adopt a water-saving technology	(2) Switch to a drought-resistant variety	(3) Sacrifice lower value crops
α_i (intercept)	-3.26** (1.62)	-3.26*** (1.12)	-5.84*** (1.49)
β_i (% crop harvested)	9.05*** (3.35)	6.11*** (1.89)	10.31*** (2.52)
WTA_i	36.0%**	53.3%***	56.6%***
N of obs.[1]	59	60	59
Log-Lik.	-20.45	-33.57	-26.08
Wald χ^2	7.29***	10.49***	16.71***

*** denote significance at 1% level. Standard errors are in parentheses. WTA_i is calculated as $-(\alpha_i/\beta_i) * 100\%$. Confidence intervals for WTA determined using Krinsky & Robb method with 10,000 replications.

[1] In total, 20 growers answered at least one of the three choice questions (with varying levels of crop yield), related to each one of the three strategies. Thus, maximum number of observations per strategy is 60. Reported number of observations indicate that at most one response was missing for a given strategy.

Table 3. PML model results for hay/forage growers

Strategy	(1) Switch to a more efficient irrigation system	(2) Adopt a water-saving technology	(3) Switch to a low water-use crop/variety
α_i (intercept)	-1.38* (0.80)	-3.00*** (0.88)	-2.79*** (0.85)
β_i (% crop harvested)	3.59*** (1.36)	6.43*** (1.56)	5.60*** (1.45)
WTA_i	38.5%*	46.7%***	49.9%***
N of obs.[1]	104	104	100
Log-Lik.	-60.67	-54.55	-56.36
Wald χ^2	6.95***	17.00***	14.84***

***, **, and * denote significance at 1%, 5%, and 10% level, respectively. Standard errors are in parentheses. WTA_i is calculated as $-(\alpha_i/\beta_i) * 100\%$. Confidence intervals for WTA determined using Krinsky & Robb method with 10,000 replications.

[1] In total, 35 growers answered at least one of the three choice questions (with varying levels of crop yield), related to each one of the three strategies. Thus, maximum number of observations per strategy is 105. Reported number of observations indicate that only a few responses were missing for a given strategy.

Table 4. Share of respondents selecting each strategy as most preferred

Order	Fresh produce growers	Hay/forage growers
#1	Water saving technology (40%)	Change to a low water-use crop/variety (33%)
#2	More water efficient irrigation system (25%); Sacrifice lower value crops (25%)	Adopt a water saving technology (27%)
#3	Change to a drought resistant crop (10%)	More water efficient irrigation system (24%)
#4	Move out of farming (0%)	Move out of farming (15%)
N	20	33

Table 5. Preferences for strategies across subgroups of fresh produce growers

Characteristic	Category	(1) Adopt a water-saving technology	(2) Switch to a drought-resistant variety	(3) Sacrifice lower value crops
Gender of the primary operator	Male	39.1%**	62.3%***(a)	53.6%***
	Female	34.8%**	39.4%**(a)	58.5%***
Primary sales outlet	Direct only	40.7%**	54.3%***	59.9%***
	Other	24.7%	51.2%***	49.4%***
Acres farmed	<=10 acres	37.6%**	48.6%***(a)	57.1%***
	>10 acres	16.2%	81.6%***(a)	56.5%***
Primary crop	Vegetables	36.9%**	48.9%***(a)	55.4%***
	Other	32.4%*	80.9%***(a)	63.4%***
Irrigation system used primarily	Drip	41.5%**(a)	53.7%***	60.6%***(a)
	Other	14.5%(a)	52.1%***	45.2%***(a)
Mulch applications used before	Yes	38.0%**	48.7%***(a)	57.1%***
	No	28.9%	72.5%***(a)	54.8%***
Wind breaks used before	Yes	31.9%*	46.7%***	51.4%***(a)
	No	41.0%**	61.4%***	63.3%***(a)
Cover crops used before	Yes	40.4%**	49.1%***	62.8%***(a)
	No	30.7%*	58.5%***	48.8%***(a)
Large % of crop loss	<40%	36.1%**	46.7%***	51.4%***
	=>40%	36.1%**	57.8%***	60.0%***

Values represent minimum percentage of crop harvested at which fresh produce growers are willing to adopt a strategy. ***, **, and * denote significance at 1%, 5%, and 10% level, respectively. Same letter (a) indicates statistically significant difference in the WTA estimates across the subgroups (within a strategy and characteristic).

For example, those who farm on 10 acres or less are willing to switch to a drought-resistant variety significantly more (min. crop harvested 48.6%) than those who farm on more than 10 acres (min. crop harvested 81.6%).

Table 6. Preferences for strategies across subgroups of hay/forage growers

Characteristic	Category	(1) Switch to a more efficient irrigation system	(2) Adopt a water-saving technology	(3) Switch to a low water-use crop/variety
Gender	Male	38.2%*	48.6%***	52.4%***(a)
	Female	41.1%	27.0%	24.2%(a)
Primary sales outlet	Direct	42.0%*	49.4%***	57.0%***(a)
	Other	36.3%	44.5%***	41.1%***(a)
Acres farmed	0-100 acres	21.4%(a)	53.6%***(a)	48.5%***
	101-300 acres	55.7**(a,b)	35.4%**(a,b)	56.2%***(a)
	301-1000 acres	24.8%(b)	58.4%***(b)	54.1%***
	> 1000 acres	49.1%**	47.3%***	29.3%(a)
Primary crop	Alfalfa hay	53.5%**(a)	53.8%***(a)	60.5%***(a)
	Livestock	27.2%(a)	38.5%***(a)	48.6%***(b)
	Other	22.9%	47.2%***	18.0%(a,b)
Irrigation system used primarily	Flood	72.0%***(a,b)	46.9%***	63.6%***(a)
	Pivot	38.3%*(a)	44.6%***	50.0%***
	Wheel line	26.7%(b)	48.7%***	44.6%***(a)
Cover crops used before	Yes	30.7%	41.1%***	47.4%***
	No	37.6%	54.0%***	48.4%***
Manure applications used before	Yes	46.5%**(a)	47.6%***	55.3%***(a)
	No	37.8%(a)	37.4%**	14.1%(a)
Large % of crop loss	0-39%	36.3%	40.6%***	46.9%***
	40-59%	31.7%	49.3%***	45.1%***
	60-99%	49.0%**	48.5%***	57.5%***

Values represent minimum percentage of crop harvested at which hay growers are willing to adopt a strategy. ***, **, and * denote significance at 1%, 5%, and 10% level, respectively. Same letter (a or b) indicates statistically significant difference in the WTA estimates across the subgroups (within a strategy and characteristic). For example, those who primarily use wheel line irrigation are willing to switch to a low water-use crop significantly more (min. crop harvested 44.6%) than those who primarily use flood irrigation (min. crop harvested 63.6%). For example, those who farm on 10 acres or less are willing to switch to a drought-resistant variety significantly more (min. crop yield needed 48.6%) than those who farm on more than 10 acres (min. crop yield needed 81.6%). For example, those who farm on 10 acres or less are willing to switch to a drought-resistant variety significantly more (min. crop yield needed 48.6%) than those who farm on more than 10 acres (min. crop yield needed 81.6%).

Appendix: Example of choice tasks provided to fresh produce growers.

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you adopt a water saving technology such as wind break, cover crop, or mulch application, etc. you will still harvest at least 80% of your crops.
Do you switch, yes or no?

○ Yes

○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you adopt a water saving technology such as wind break, cover crop, or mulch application, etc. you will still harvest at least 40% of your crops.
Do you switch, yes or no?

○ Yes

○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you adopt a water saving technology such as wind break, cover crop, or mulch application, etc. you will still harvest at least 60% of your crops.
Do you switch, yes or no?

○ Yes

○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crop.

If you switch to a drought-resistant variety you will still harvest at least 60% of your crop.
Do you switch, yes or no?

○ Yes

○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crop.

If you switch to a drought-resistant variety you will still harvest at least 80% of your crop.
Do you switch, yes or no?

○ Yes

○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you switch to a drought-resistant variety you will still harvest at least 40% of your crop.
Do you switch, yes or no?

○ Yes

○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you sacrifice your lower value crops you will still harvest at least 80% of your other crops.
Do you do this, yes or no?

- ○ Yes
- ○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you sacrifice your lower value crops you will still harvest at least 40% of your other crops.
Do you do this, yes or no?

- ○ Yes
- ○ No

You have 50 acres, where you grow your current primary crops.
Due to drought you could loose a large percentage of your crops.

If you sacrifice your lower value crops you will still harvest at least 60% of your other crops.
Do you do this, yes or no?

- ○ Yes
- ○ No